Water Resources Research Center
Annual Technical Report
FY 2016

Introduction

In 2013, Hawaii’s Water Resources Research Center (WRRC) was assigned an added responsibility as the WRRIP Center for American Samoa. Freshwater resources in island states, including Hawaii and American Samoa, are under threat caused by competing demands and contamination. Climate change and population growth have resulted in the diminishing supply of potable water. As the world faces escalating demands for suitable freshwater, current usage is negatively affecting surface and groundwater supplies. This is more severe in island environments, which have a low buffering capacity and thus are highly vulnerable to climate change. WRRC has continued to address issues related to water demand and quality problems critical to Hawaii, American Samoa, and the Pacific. When compared to continental areas, such issues are more critical because of these areas’ geographic isolation, unique hydrological features, and small land areas. Added responsibilities included studies on American Samoa, which were aimed at establishing research studies dealing with this Territory’s water demands, water quality, and land-ocean interactions.

Research Program Introduction

Studies during this reporting period addressed important and critical water problems for Hawaii and American Samoa. They can be grouped to those dealing with water conservation, drinking water and environmental quality, and overall understanding of watershed processes.

A study was motivated by the fact that land-use practices, such as agricultural regimes, significantly impact the state of coastal biological communities, via tainting submarine groundwater discharge (SGD). Sustainable land-use practices that put a premium on developing best practices for future farming and wastewater techniques, must consider the full ramifications land-based sources of pollution, including severe 'nutrification', an ecosystem level increase in nutrients that drives algal blooms. Moreover, SGD link to coastal areas may be exacerbated by seasonal variation and global climate regimes such as El Niño.

Another study addressed watershed pollution due to pesticides, nutrients, and sediment. Contribution of baseflow to such problems can be significant. Information needed by land and water resource managers regarding the distribution and transport of pollutants are needed for the optimal design of protective measures in a watershed.

Contamination of nearshore waters by cesspools or other On-Site Disposal Systems (OSDS) is a serious problem that was tackled by a study during this reporting period. These systems can introduce sewage contamination by discharging groundwater to streams. To remedy the problem there is a need to identify the contributing areas and OSDS that are the primary source of wastewater contamination to the streams and other open water bodies.

Surface water can directly affects certain wells, such as those on Tutuila, American Samoa. On this island, the municipal water supply system is currently unable to provide potable drinking water to the island's growing population. In 2009, a boil-water advisory was issued throughout much of Tutuila's water service. However, the mechanisms and timescales of the rapid recharge of surface water to the wells remain unknown. Such issues were also covered during the reporting period.

A study also addressed the need to understand how microbial community structure and function in tropical coastal estuaries drive geochemical processes in response to climate forcing. Conditions in the Equatorial Pacific signify a developing El Niño but its current impact on environmental conditions in the Hawaiian Islands due to atmospheric tele-connections is not well defined. For Hawaii, El Niño events typically displace the subtropical jet stream, leading to decreased precipitation in boreal winter and slightly enhanced rainfall in summer as well as decreased trade winds. El Niño conditions promote temperature stratification of the water column, which will decrease oxygen availability and drive a shift in benthic biogeochemistry to more reducing conditions.

A related study addressed the fact that, currently, except a few fecal indicator bacteria being measured by the State agencies, microbes reside in Hawaii aquifers are not known. Hence, it is not possible to identify impacts to, nor recovery of the compromised aquifers based on microbiological data. This is a concern as impacts from population growth, climate change, and other hazards cannot be measured and evaluated. There is a need to provide a in depth characterization of microbial communities and sources of microbes in Honolulu's water supply. The main objectives of the study were to identify microbial community structure in the drinking water system and to determine the source of indicator bacteria.

Conservation related studies addressed the fact that island communities, such as Hawaii and American Samoa, face mounting demands on water supply due to increased consumption and climate change. The latter can cause lower rainfalls, decreased ground recharge, and redirection of rainfalls over watersheds — all of which stress pre-existing ground supply of potable water. Concerns about water shortages make it necessary to optimize use of valuable water resources. Options include watershed repair, rainwater capture, and water reuse. Irrigation scheduling is also an important measure, considering that over irrigation not only wastes water and energy but can also impair the quality of surface and groundwater and possibly the nearshore coastal waters. Crop yield decrease is also possible. The negative effects of under irrigation would obviously diminish crop yields decreasing profit margins.

Waste generation and disposal is a serious problem especially on island environments. Discharging into the ocean or through cesspools and septic systems likely causing water quality problems. Another study dealt with innovative techniques for wastewater treatment and reuse, which are of great value representing an attractive alternative.

Rainforests are recognized for their role in helping the water cycle by transpiring water to the atmosphere and contributing to rain cloud formation. Forests also protect the soil layers that store water and prevent soil erosion. Another study was motivated by the fact that there is a need to understand the response of rainforests to unique precipitation patterns at a watershed scale. For example, in some locations in Hawaii, though the rainfall intensity has increased, total rainfall has been on the decline in the last two decades and stream flow is subsequently subsiding. The analyses should address various hydrologic mechanisms, such as flow paths, groundwater recharge, evapotranspiration, and time of concentration.

The following sections summarize the research efforts for the reporting period grouped into main categories.

Drinking Water and Ecological Quality

Likely hotspots for algal blooms: A multi-dimensional analysis to evaluate seasonal impact of land-based sources of pollution on the health of American Samoa's coasts

Recent hydrological studies have shown that land-use practices, such as agricultural regimes, significantly impact the state of coastal biological communities, via tainting submarine groundwater discharge (SGD), a vector for the delivery of anthropogenic nutrients to tropical reefs. Sustainable land-use practices that put a premium on developing best practices for future farming and wastewater techniques, must consider the full ramifications land-based sources of pollution, including severe 'nutrification', an ecosystem level increase in nutrients that drives algal blooms. Moreover, the effect of the potential land-based sources of pollution, linked by SGD to coastal American Samoa may be exacerbated by seasonal variation and global climate regimes such as El Niño. Over the course of our decade-long study of algal blooms in Hawaii, the research team has developed techniques enabling identification of coastal sites where tainted groundwater discharges, offering new tools to identify hot spots – sites that may be precipitously poised to suffer significant collateral impacts if ecosystem features are altered with climate change. The objective of this study is to employ three emerging indicators of ecosystem health in sites along a human use gradient on Tutuila. The research team proposes to build on a successful WRRC-funded field season (July 2105) by examining seasonal variations, specifically the impact of El Niño, and SGD on coastal biota of Tutuila. The parameters of impaired ecosystems are variations in delta^{15}N and % N in deployed non-calcified algae, modified microbial communities as assessed by next generation sequencing, and macro-benthic surveys at impacted and reference sites. By coordinating genomic samplings for microbial diversity at the same sites where the team examines the source (tissue analysis for delta^{15}N) and the flux (tissue analysis for % N) of nitrogen, into those coastal sites, hot spots is expected to be identified for likely shifts in microbial community structure and benthic communities in potential impact sites and pristine coastal waters. Importantly, this study will enable a better understanding of SGD discharge and commensurate responses in coastal microbial communities that will aid resource managers in on-going monitoring and detection of wastewater in coastal communities.

Thus far, the 2016 data is consistent with the 2015 data set. Comparisons among the four principal locations using algal tissue delta^{15}N indicated nearly identical trends to the 2015 data set. The average algal tissue delta^{15}N values were highest at the extensively impacted locations (Fagaalu and Pala Lagoon) and lowest at the minimally impacted locations (Vatia and Oa), which indicated wastewater as a likely source of N to the coastal waters of Fagaalu and Pala Lagoons. Though the research team anticipated inter-annual variations in the parameters measured due to El Niño effects, data from 2015 and 2016 show similar trends across the locations. The study demonstrated clear linkages between land use and coastal water quality when the extensively impacted regions are compared to minimally impacted regions. In addition, it is anticipated that water chemistry at the study locations in American Samoa will be closely linked with human density and the N input from piggeries and other agricultural practices.

Stream pesticide and nutrient loads from baseflow, surface runoff and sediment contributions on Tutuila Island, American Samoa

The proposed work utilized an existing watershed model (SWAT) developed for Fagaalu, Tutuila, in combination with pesticide, nutrient, and sediment measurements, to determine the contribution of baseflow, surface runoff, and sediments to pollutant fluxes in Fagaalu Stream. This research provided important information for land and water resource managers (ASPA, AS-EPA) on the distribution and transport of pollutants during baseflow conditions and rain events so that protective measures can be developed for pollution migration downstream in the watershed. SWAT simulated suspended sediment fluxes captured the observed sediment values at the upstream dam station, the model noticeably missed a few observed sediment loading values especially during the low to medium flow events at a downstream station. Such characterizations could be related to human disturbance (or urbanization) at the lower part of the watershed, including quarry, road side and swimming activities, which cannot be easily represented in the model.

In order to assess the groundwater's role as a pollution pathway, in situ samples were collected in the watershed. These show comparable levels of glyphosate and nitrate as found in other watersheds on the island with anthropogenic influences. The research team found that stream and stream bank groundwater had comparable levels of pesticides in both gaining and losing reaches of the stream. In addition, glyphosate was detected in both coastal springs. Groundwater is therefore a possible pathway for glyphosate migration. Groundwater flowpaths of all samples were simulated using a hydrological model. Our findings indicate that glyphosate concentrations in the watershed are low (in comparison to U.S. Environmental Protection Agency aquatic health benchmarks) but it is present in both ground and stream water. Higher pesticide levels correlate with shorter groundwater flow paths in the central part of the watershed and also in the coastal plain.

Identifying groundwater flow and contamination to streams: Kahaluu watershed, Oahu

The surface waters in the Kahaluu Lagoon on the windward side of Oahu fronted by Kaneohe Bay have been shown to have very high levels of wastewater indicator bacteria. Watersheds feeding this lagoon contain over 1,000 cesspools or other On-Site Disposal Systems (OSDS). While some introduction of sewage contamination may be due to overflow during storm events, there is also chronic introduction of sewage contamination by the discharge of groundwater to streams. Therefore, the goal of this project is to assess the hydraulic connectivity between OSDS and other land use and the oceanic waters of Kaneohe Bay, Oahu, with particular focus on the Bay's Kahaluu watershed, an area well known for particularly high density of OSDS, historic high risk for groundwater contamination, and a propensity for repeated clean water violations.

Our objectives have been to investigate flow paths of contaminant transport from known occurrences of OSDS and other land use by integrating: (1) infrared mapping of groundwater seepage to streams, lagoon, and ocean with thermal infrared UAV Drone; (2) location and quantification of groundwater flow to streams and stream flow to ocean by stream gauging and stream seepage runs; (3) radon-222 and radon-220 activity surveys and continuous monitoring; and (4) groundwater monitoring and flow path modeling. To these initially stated objectives the research team are now incorporating (5) field-based studies of nutrient sources, loads and transformations using major element geochemistry and stable isotopes.

Year-1 UAV drone infrared imaging efforts included extensive UAV pilot training for FAA licensing, reconnaissance flights, and initial field data collection in Kahaluu study sites, particularly in areas of major stream confluence at Kahaluu Lagoon, as well the adjacent shoreline of Kaneohe Bay. Flights were ground-truthed with in situ temperature loggers to verify and calibrate UAV-TIR data. The team established that this method allows us to easily identify and delineate areas of groundwater discharge to the lagoon and adjacent ocean, distinguish between point source and diffuse discharge, and quantify the thermal gradients. Imagery processing and mosaicking is ongoing, with future flights planned for stream reaches and other coastal areas. The research team has also been measuring and utilizing radon-222 and radon-220 (naturally present in the groundwater but occurring only in trace quantities in streams) as groundwater tracers from our surveys to further identify and collaborate groundwater outcrops and quantify groundwater flow into the streams and lagoon. To date, correlations between these parameters and our detection of groundwater inputs by UAV-TIR have been excellent.

Stream gauging locations in Kahaluu and Waihee Streams have been established upstream using USGS gauging stations and downstream by installing new permanent gauging stations. Permanent transducers installed at these stations are being used to monitor both daily and seasonal inputs and outputs. Piezometers were installed in the water table adjacent to each stream gauge to monitor groundwater. Because the gain (or loss) of groundwater to streams is the algebraic difference between consecutive stream flow measurements (corrected for the contribution from tributaries and reduction to diversions), the gauging stations also serve as anchor points for midstream segmented groundwater seepage runs currently in progress. Volumetric discharge measurements are underway under varying conditions using an acoustic FlowTracker Doppler Velocitimeter to establish stream height discharge relations (i.e., a rating curve). Baseline nutrient and stable isotope geochemical analyses have also been completed in the Kahaluu region streams and lagoon. Ground- and surface-water samples of Kahaluu and Waihee watersheds show a denitrification trend with a 2:1 ratio of delta$^{15}N_{nitrate}$ to delta$^{18}O_{nitrate}$.

Isotopic compositions correlate with manure and septic waste input, but additional contributions of nitrate may include manure and fertilizer from range and agricultural land. Preliminary analysis of nitrate concentration and isotopic composition in Waihee Stream show an enrichment factor for the stream characteristic of denitrification in an agricultural setting. On a more long-term basis, the research team has further established a network of rainfall collectors the region to aid in differentiating groundwater sources and pathways using the isotopes of water (deltaD and delta^{18}O) from rain, wells, and down-gradient groundwater and surface water. A steady-state groundwater model (GMS: MODFLOW) has been configured and calibrated to delineate groundwater flow gradients, and a transient groundwater model (GMS: MT3DMS) constructed to simulate the subsurface transport of OSDS nitrogen. When coupled with OSDS use and distribution data, the models will be used to predict the extent of OSDS nutrient pollution in Kaneohe Bay, as well as potential remediation scenarios.

Microbial communities and sources of bacteria in Honolulu's water supply

Currently, except a few fecal indicator bacteria being measured by the State agencies, microbes reside in Hawaii aquifers are not known. Hence, researchers are unable to identify impacts to, nor recovery of the compromised aquifers based on microbiological data. This is a concern as impact from population growth, climate change, and other hazards cannot be measured and evaluated. The overarching goal of the project is to provide first in depth characterization of microbial communities and sources of microbes in Honolulu's water supply. The two main objectives are to: (1) identify microbial community structure in our drinking water system (source water and distribution system); and (2) determine the source (sewage, soil, or biofilm) of indicator bacteria, if found, in the well and tunnel water samples. To achieve this goal, are analyzing microbial communities using next-generation sequencing techniques (partial 16S RNA gene amplicon sequencing on Illumina platform) in Oahu's groundwater and distribution water samples. In addition, the project researchers are analyzing these samples for cultivable fecal indicator bacteria (total coliforms, *Escherichia coli, Clostridium perfringens,* F+ specific coliphages) and molecular sewage-specific markers (human-associated *Bacteroides* and human polyomaviruses). During the first year of the study, 36 source water and 36 soil samples adjacent to the wells were collected. Six of those source water samples (17%) were positive for total coliforms, while no *E. coli* or *C. perfringens* were detected in any of the water samples analyzed. No sewage-specific markers (human-associated *Bacteroides*, human polyomavirues), nor coliphages were detected in any of the source water samples. Coliform bacteria in the positive source water samples could originate from: (1) biofilms, and/or (2) leach from soils. In this regard, all soil samples were positive for total coliforms and enterococci. Geometric mean concentrations of both organisms in soil samples were 450 MPN/g and 22 MPN/g of soil respectively, but frequently exceeded >2,419.6 MPN/g of soil. *E. coli* was detected in 55% of soil samples (geometric mean 13 MPN/g of soil). Unfortunately, no biofilm samples could be collected from the wells. Our data collected so far indicates that total coliforms in source water samples do not originate from sewage. Microbial community analyses will provide further evidence on the source of bacterial contaminants and associated risks. This will be completed on all samples collected (including soil samples) once the research team has finished collecting samples from the distribution system.

Assessing recharge mechanisms of groundwater under the influence of surface water with isotopic and microbiological tracers, Tutuila, American Samoa

On Tutuila Island, in the Territory of American Samoa, the municipal water supply system is currently unable to provide potable drinking water to the island's growing population. In 2009, a boil-water advisory was issued throughout much of Tutuila's water service area due to elevated turbidity and *Escherichia coli* detections in supply wells from the island's most productive aquifers located below the Tafuna-Leone Plain. Although it is clear that surface water directly affects certain wells on Tutuila, the mechanisms and timescales of this rapid recharge remain unknown. Our objectives are to develop a better understanding the mechanisms and timescales of recharge to the wells in this region by using multiple data sources including geochemical and isotopic tracers, physical aquifer data, and bacteriological tracers. Methods include, assessing variation in delta^{2}H and delta^{18}O values in precipitation and groundwater, using microbial indicators and cosmogenic isotopes to assess aquifer material properties, and assessing physical aquifer response to rain events. Monthly sampling of water isotopes in precipitation has shown distinct trends in seasonality, whereas groundwater samples lack this trend indicating that significant flushing of these aquifers does not occur on a seasonal basis. Bacteriological sampling clearly indicates a significant difference between GUDI wells, which consistently test positive for total coliform and *E. coli,* vs. non-GUDI wells, which consistently test negative. Informed development of future water resources depends on a clear understanding of the hydrogeological dynamics of the Tafuna and Leone Aquifers.

Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem

The overarching goal of this work is to understand how microbial community structure and function in tropical coastal estuaries drive geochemical processes in response to climate forcing. Conditions in the Equatorial Pacific signify a developing El Niño but its current impact on environmental conditions in the Hawaiian Islands due to atmospheric tele-connections is not well defined. For Hawaii, El Niño events typically displace the subtropical jet stream, leading to decreased precipitation in boreal winter and slightly enhanced rainfall in summer as well as decreased trade winds. Samples are analyzed to assess changes in microbial diversity and metabolic potential within the Heeia Coastal Ocean Observing System (Hawaii, USA), a network of sites within a coastal embayment across a salinity gradient. Over the past 10 years, the on-going time series has conducted monthly (or more frequent) sampling and maintained in situ instruments, to record physical and biogeochemical variability in this estuarine system and the adjacent coastal ocean. In addition to providing a data-rich physical and biogeochemical baseline for interpreting the proposed microbial work, this accessible field site enables repeat sampling and more robust analyses that will inform us about seasonal variation in microbial community diversity and function. To help interpret patterns from field samples, enrichment experiments manipulating concentrations of nutrients are incubated in situ as well as in vitro simulations of water column temperature gradients are conducted jointly. These analyses test two hypotheses about the environmental factors driving microbial community structure: (1) increased sea surface temperatures will alter the frequency of extreme events such as flooding and tropical cyclone/hurricane activity, leading to increased mixing of estuarine environments as well as increased inputs of terrestrially-derived nutrients to the coastal ocean from surface runoff and groundwater input, and (2) El Niño conditions promote temperature stratification of the water column**,** which will decrease oxygen availability and drive a shift in benthic biogeochemistry to more reducing conditions.

During this reporting period, archived samples were DNA extracted and processed for Illumina 16S sequencing. Sequencing was completed and the research team is in the process of analyzing the data to determine which biogeochemical and physical parameters co-vary with microbial community dynamics. Starting in January 2017, sampling regime are being augmented to determine how restoration has altered the fishpond water budget. We deployed current meters into each of the sluice gates to measure water exchange over several tidal cycles including the newly built Kahookele sluice gate. The objective is to calculate volume and nutrient flux over tidal cycles. Finally, multivariate analysis was applied to characterize the structure of the water column in the fishpond. We identified two zones dominated primarily by low salinity, low dissolved O_2, and cooler water on the landward side of the mangrove island. The ocean and first river makaha can be binned into two zones with oceanic characteristics. Of these two oceanic zones, the more southwestern makaha has much higher dissolved oxygen (DO), temperature, and pH. Finally, a mid-pond zone characterized by median temperature, salinity, and pH values was observed. It is hypothesized that microbial communities will partition along these zones.

Conservation

Real-time optimization of irrigation scheduling for farmlands in American Samoa

In some regions of American Samoa, water is by far the major constraint to crop production. Even areas with abundant rainfall experience a high seasonal variability that does not maintain adequate water for the crops throughout the year. High temperature and evapotranspiration rate, in combination with limited water storage capacity of soil, also reduce water availability for crops. On the other hand, the limited supply of water is subject to ever increasing demands. American Samoa (like many other places) is growing in population and it is important to implement water conservation measures to stretch supplies as long as possible. One of the easiest and most effective ways to conserve the water resources in American Samoa is to design an optimal irrigation scheduling.

Our utilized irrigation scheduling algorithm needs: (1) weather station-derived evapotranspiration and (2) soil water holding capacity to estimate the appropriate irrigation interval and volume of water to apply. In the first year of this project, a genetic expression programming (GEP)-based algorithm was developed to estimate evapotranspiration from limited climatic data. Four different data combinations were utilized to train, test, and validate the GEP model. These were: daily mean air temperature, wind speed, relative humidity, and solar radiation (configuration 1); daily mean air temperature and solar radiation (configuration 2); daily mean air temperature and relative humidity (configuration 3); and daily maximum, minimum, and mean air temperature, and extraterrestrial radiation (configuration 4). Climatic data from eight weather stations in Iran were used to train and test the proposed GEP model. These stations were chosen to cover different hydrological conditions. Thereafter, the developed GEP model was validated with climatic data from seven California Irrigation Management Information System (CIMIS) weather stations. The results showed that the GEP model can successfully estimate evapotranspiration from climatic data. It was also found that the first data combination generated the most accurate evapotranspiration values.

Wastewater treatment for point source processing and reuse

Water limited “island” communities, such as those in Hawaii, face mounting demands on water supply, such as increased consumption, lower rainfalls, decreased ground recharge, and redirection of rainfalls over natural watersheds — all of which stress pre-existing ground supply of potable water. Of the many options in Hawaii (e.g., conservation, watershed repair, rainwater capture) the most obvious but least employed is the recycle of treated wastewater. This is both unfortunate and unwise; approximately 100 million gallons per day of water pass through Hawaii's wastewater treatment plants prior to its discharge into the ocean. There are also at least 100,000 cesspools in Hawaii, most if not all of which are designed to discharge its water without reuse. Given Hawaii's year round sunshine, land limitations, growing population, and isolation from mainland markets, an attractive use of recycle water in Hawaii is to grow edible/energy crops using high-density hydro/aeroponic technologies in greenhouse "malls". The cost of producing recycled R1 water is not the only detriment to its commercial use. The main technologies used to produce R1 water (e.g., aerated activated sludge beds and membrane reactors) remove micro and macronutrients through the production of biomass or filtration. This diminishes the value of the treated water as a resource to irrigate food or energy crops. The cost of producing R2 water, by contrast, is lower and tends to retain plant available macronutrients. As such, the production of R2 water (in lieu of R1) and its recycle for irrigation of edible, energy, or horticulture crops makes it an attractive alternative.

The objective of this study is to demonstrate the efficacy of low-energy low-chemical biofilm anaerobic-aerobic reactor systems to realize the efficient degradation of enteric pathogens. The project evaluates the survivability of the indicator organisms *Escherichia coli* and F+ specific RNA coliphages through different stages in a biofilm-based high rate anaerobic-aerobic digestion (HRAAD) reactor system. The HRAAD system was comprised of a biochar packed upflow anaerobic reactor (AnPB), a biochar packed aerobic trickling filter (TF), and a clarifier or settling tank (ST) all connected in the series. Synthetic wastewater was inoculated with *E. coli* CN-13 and bacteriophages MS2 at concentrations mimicking their concentrations in sewage.

The HRAAD system was loaded with the simulated sewage spiked with indicator organisms and the performance monitored for 73 days. In average, one log reduction of *E. coli* and 0.5 log reduction of bacteriophage MS2 was achieved across AnPB. The HRAAD system was able to achieve approximately three log reductions of *E. coli* CN-13 and almost one log reduction of bacteriophage MS2. The system performance in reducing indicator organisms, (i.e., *E. coli* CN-13 and bacteriophage MS2) over time across HRAAD system components was noted. The background concentrations (before inoculation) of indicator organisms in liquid phase samples were nominal compared to the concentrations of these organisms maintained in the feed. The *E. coli* CN-13 concentrations for the feed tank, AnPB, TF, and, ST were <10 MPN l^{-1}, 5483 MPN l^{-1}, 181 MPN l^{-1}, and 52 MPN l^{-1}, respectively. The bacteriophage MS2 was not detected in the system.

Watershed Processes

Understanding the hydrology of a rainforest watershed in Hawaii

Freshwater is a critical driver for island ecosystems. In Hawaii, the major sources of water are rainfall derived by trade wind clouds, which supply the surface flow and recharges the ground aquifer. Though the rainfall intensity has increased, total rainfall has been on the decline in the last two decades and stream flow is subsequently subsiding. Rainforests are recognized for its role in helping the water cycle by transpiring water to the atmosphere and contributing to rain cloud formation. Forests also protect the soil layers that store water and prevent soil erosion. Lyon Arboretum is the only accessible tropical rainforest on the island of Oahu. With its unique location and topography, this watershed receives frequent and intense rainfall. In the first year of this study, the research team set up one monitoring station and has visited the watershed multiple times to select monitoring locations. The team conducted several flow measurements to develop stream flow rating curves. One of the goals of this study is to understand hydrologic mechanisms, such as flow paths, groundwater recharge, evapotranspiration, and time of concentration. As it is naturally covered, the watershed of Lyon Arboretum provides an excellent example to understand stream flow of rainforest at an undisturbed condition. With that information, nutrient and sediment transport and their contribution to downstream watershed can be described. In the meantime, a hydrologic model is being built that will utilize the monitoring data. This sets a baseline for future studies on exploring hydrologic mechanisms and nutrient transport under disturbed conditions (e.g., anthropogenic land use, stream diversions, and groundwater withdraw). The established knowledge of plant species in Lyon Arboretum provides a great source to understand rainforest evapotranspiration and its interaction with cloud formation. With the projected decline, yet intensity-increased rainfall under future climate, this project is helping us prepare for these changes upon rainforest and the respective freshwater availability for human and natural ecosystems.

Effects of upland pollution on benthic communities around Tutuila, American Samoa.

Basic Information

Title:	Effects of upland pollution on benthic communities around Tutuila, American Samoa.
Project Number:	2016AS453B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Nutrients, Sediments
Descriptors:	None
Principal Investigators:	Julie Helen Bailey-Brock

Publication

1. There are no publications for 2016.

Abstract

We are planning to follow-up in August 2017 to strengthen and further discuss issues in American Samoa on water/water issues. The funds for 2016AS453B (Effects of Upland Pollution on Benthic Communities Around Tutuila, American Samoa) was used to carry out integrative consultations with the water sector stakeholders in American Samoa through a full day workshop in Pago Pago and through related field visits. The aim was to strengthen the WRRIP program and its implementation in American Samoa, provide an opportunity for WRRC to understand the requirements and priorities of stakeholders in American Samoa, and to identify local research partners and project opportunities.

Introduction

The Water Resources Research Center (WRRC) at the University of Hawaii at Manoa began administration of the State Water Resources Research Program for American Samoa in 2013. It was proposed (under this project) to carry out an integrative consultation with the stakeholders of the water sector in American Samoa through a full day workshop in Pago Pago and related field visits. The aim was to strengthen the Water Resources Research Institute Program (WRRIP) and its implementation in American Samoa by increasing awareness of the program among the local stakeholders, as well as providing an opportunity for WRRC to understand the requirements and priorities of stakeholders in American Samoa, and to identify local research partners and project opportunities. This project was conducted in the Spring of 2016 (as the principal investigator was on sabbatical during 2014–2015).

Problem and Research Objectives

The administration of the American Samoa WRRIP program was initially difficult as researchers at WRRC had no firsthand knowledge of the ground realities in American Samoa and in-person communication with concerned stakeholders in American Samoa was difficult due to the distance from Hawaii. Several remote telephone calls with key players in American Samoa were carried out early on, yet an integrative consultation with the stakeholders of the water sector needed to be carried out to improve the implementation of WRRIP and other associated water sector activities. For this purpose WRRC personnel held a workshop in American Samoa with stakeholders from the American Samoa Community College, American Samoa Environmental Protection Agency, American Samoa Power Authority (the agency in charge of the public water system), American Samoa Coral Reef Advisory Group, and US National Parks.

Workshop participants included:

- Scott Burch, Superintendent of the National Park of American Samoa
- Alice Lawrence, Fisheries Supervisor, American Samoa Department of Marine and Wildlife Resources
- Timothy Bodell, Engineer, American Samoa Environmental Protection Agency
- Jason Jaskowiak, Chief Engineer, American Samoa Power Authority
- Katrina Elaine Mariner, Water and Wells System Engineer at American Samoa Power Authority
- Jewel Tuiasosopo, Chief, Water Quality Branch, American Samoa Environmental Protection Agency
- Will Spitzenberg, Senior Water Engineer, American Samoa Power Authority
- Ian Gurr, American Samoa Community College
- Mark Schmaedick, American Samoa Community College
- Kelly Anderson, Tagarino, Extension Agent, University of Hawaii Sea Grant College Program
- Meagan Curtis, Watershed Coordinator, American Samoa Department Of Marine and Wildlife Resources Coral Reef Advisory Group

- Antonina Teo, American Samoa Environmental Protection Agency
- Mareike Sudek, Coral Reef Ecologist, American Samoa Department Of Marine and Wildlife
- Resources Coral Reef Advisory Group
- Kristine Bucchianeri, American Samoa Department of Marine and Wildlife Resources, Coral Reef Advisory Group
- Sabrina Woofter, American Samoa Department of Marine and Wildlife Resources, Coral Reef Advisory Group
- Lise Soli, American Samoa Environmental Protection Agency
- Gina Faiga, American Samoa Department of Commerce, Coastal Zone Management Program

The objectives of the meeting were to establish and enhance linkages to local institutions and individuals to facilitate better administration of the WRRIP program, increase WRRC's awareness of the requirements and priorities of water issues in American Samoa, and to identify local research partners and opportunities. The visit provided avenues to develop cooperation, explore research ideas, and gain better understanding of the field realities in American Samoa. The mandate of WRRC includes an obligation to broadly disseminate the results of its research activities to audiences of local water and wastewater agencies, environmental engineering consultants, other academic researchers, and interested members of the public in American Samoa. This meeting provided an opportunity to inform local stakeholders in American Samoa about the WRRIP program.

Methodology

A three-member team traveled to American Samoa to conduct the workshop, to discuss areas of concern with various officials and local personnel, and gather stakeholder input in identifying American Samoa's research needs. Informational material about WRRC was distributed to the Amercian Samoa stakeholders to promote awareness of the Center's activities.

Project Outcome

A workshop took place on January 11, 2016. Each of the participants presented their priorities and concerns about water issues needing research in American Samoa. The presentations largely reflected the fields of specialization of the participants, but together gave a broad picture of priorities in the territory. As could be expected for an island, much concern about threats to the nearshore environment by pollution were expressed by most of the participants.

The following is a list of issues that were brought up by the participants during the meeting as being of special concern to them as water stakeholders in American Samoa.

- Revision, updating of groundwater protection/recharge areas and associated modeling.
- Building the capacity of the American Samoa Power Authority in regards to groundwater modeling and hydrologic monitoring.

- Identification of new groundwater sources—possibly high-level, impounded sources.
- Optimization of designs for septic systems appropriate for the island's volcanic geology.
- Use of models in decision making for septic system permits.
- Investigation of nearshore water quality, especially in regard to nutrients, algal blooms in Olosega Lagoon.
- Crown of thorns starfish population boom in Pago Pago Harbor area.
- Island lacks a pumping truck to empty cesspools.
- The enrichment of waters where corals grow by groundwater and the relationship of this to fish toxins.
- Monitoring of reefs relative to watershed activities.
- Biomonitoring of fish in nearshore waters.
- Source tracking of nutrients flowing from watersheds to the ocean.
- Post harvest wash water microbial quality for vegetable farmers to protect public health.
- Identifying a method of rapid testing for microbial water quality in wash waters or agricultural waters.
- Aunu'u Island taro field salinization issues. Monitoring, modeling to identify sources and causes
- Increased loading of nutrients and agricultural chemicals to waters due to increased vegetable farming. Education for farmers regarding optimal dosing of such chemicals and related issues. Most of the new farmers are immigrants from Asia and there are some communication/cultural/enforcement issues.
- Pesticide contamination of groundwater due to increased vegetable farming.
- Impact of sedimentation on corals.
- Microbial influxes and their effect on corals.
- Science communications: in general and in specific forms that are accessible to Samoan population.
- The microbial safety of "village" water systems—pipes that bring water from streams to houses in villages.
- Engineering assistance in the design of such village water systems.
- Need to fill a vacant water researcher position at the American Samoa Community College. Training of such a person will be needed.
- More gaging of streams.
- Identification/monitoring of shellfish toxins.
- Disinfection byproducts in the public water system.
- Toxicity testing of water in Pago Pago Harbor. Monitoring of heavy metals from the cannery and shipyard?
- High bacteria counts in recreational waters around Pago Pago Harbor.
- Trash reduction in nearshore waters.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

None

Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa

Basic Information

Title:	Assessing Recharge Mechanisms of Groundwater Under the Influence of Surface Water with Isotopic and Microbiological Tracers, Tutuila, American Samoa
Project Number:	2016AS454B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Quality, Water Use, Solute Transport
Descriptors:	None
Principal Investigators:	Marek Kirs, Craig R Glenn

Publication

1. There are no publications for 2016.

Problem and Research Objectives

On Tutuila Island, in the Territory of American Samoa, the municipal water supply system is currently unable to provide potable drinking water for the island's growing population. In 2010, a boil-water advisory was issued throughout much of Tutuila's water service area due to elevated turbidity and *E. coli* detections in the supply wells from the island's most productive aquifers located below the Tafuna-Leone Plain (ASEPA 2016). Previous studies have shown some of these wells experience short groundwater recharge times during heavy rain events, and produce Groundwater Under the Direct Influence (GUDI) of surface water (ASPA 2012). The area served by GUDI wells is large, and this ongoing issue has made Tutuila's boil-water-advisory one of the longest in U.S. history.

Although it is clear that surface water directly affects certain wells on Tutuila, the mechanisms and timescales of this rapid recharge remain unknown. Two hypothesized mechanisms are (1) highly-permeable aquifer material allows surface water to infiltrate and contaminate the entire aquifer, or (2) improperly constructed well casings or packings allow small amounts of localized surface water to infiltrate through the well bore itself. Informed development of future water resources depends on a clear understanding of the hydrogeological dynamics of the Tafuna and Leone Aquifers.

Our objectives are to develop a better understanding of the mechanisms and timescales of recharge to the wells in this region by using multiple data sources, including geochemical and isotopic tracers, physical aquifer data, and bacteriological tracers. This multi-tracer approach encompasses:

1. Establishing a quantitative understanding of the baseline variation in δ^2H and $\delta^{18}O$ values in precipitation and groundwater on the island of Tutuila, American Samoa.
2. Utilizing the above isotopic relationships to constrain the timing and mechanisms of surface water recharge in production wells by measuring water isotope values over long time-scales (multiple seasons) and short timescales (over discrete heavy rain events).
3. Assessing production well contamination vulnerability with microbial indicators measured over long- and short-timescales.
4. Assessing physical aquifer response to rainfall by measuring transient water levels and reviewing borehole log data.
5. Determining the physical properties of aquifer material with cosmogenic particle-reactive isotopic tracers such as ^7Be.

Methodology

Assessing Variation in δ^2H and $\delta^{18}O$ Values in Precipitation and Groundwater

We are assessing the isotopic composition of δ^2H and $\delta^{18}O$ in precipitation with cumulative precipitation collectors, following the design of those used by Scholl et al. (1996). Collectors, as well as nearby groundwater wells, are sampled monthly and the samples are analyzed with a Picarro L1102-i Isotopic Liquid Water Cavity Ring-Down Spectrometer. We are also assessing variation in δ^2H and $\delta^{18}O$ on short-timescales by sampling both GUDI and non-GUDI wells at high resolution during heavy rain events.

Microbial Indicators and Cosmogenic Isotopes to Assess Aquifer Material Properties

Presence of short-lived endogenous or soil bacteria species in groundwater indicates both lack of filtration capacity of aquifer material (Entry and Farmer 2001) and short groundwater travel times, since *E. coli* die off rates in this environment may be greater than 50% per day (Foppen and Schijven 2006). To assess the variability of these factors between wells, we are also sampling both GUDI and non-GUDI wells on monthly intervals and during high-rain events for total coliform (TC) and *E. coli* bacteria with Colilert-18® tests in Quanti-Tray®/2000 format. Additionally, particle reactive cosmogenic isotopes of ^{7}Be have the potential to be used in a similar manner to elucidate the filtration capacity of aquifer material and recharge travel time (Veselý et al. 2002). During planned fieldwork in April 2017, we will sample groundwater, surface water, and precipitation for ^{7}Be. Concentrations of ^{7}Be will be assessed with a High-purity Germanium Crystal Gamma Spectrometer at the University of Hawaii.

Assessing Physical Aquifer Response

Water level data and video logs are currently being collected from the American Samoa Power Authority to better understand aquifer response to heavy rains or seasonal variation. Video logs will be used to confirm well construction information as few records exist.

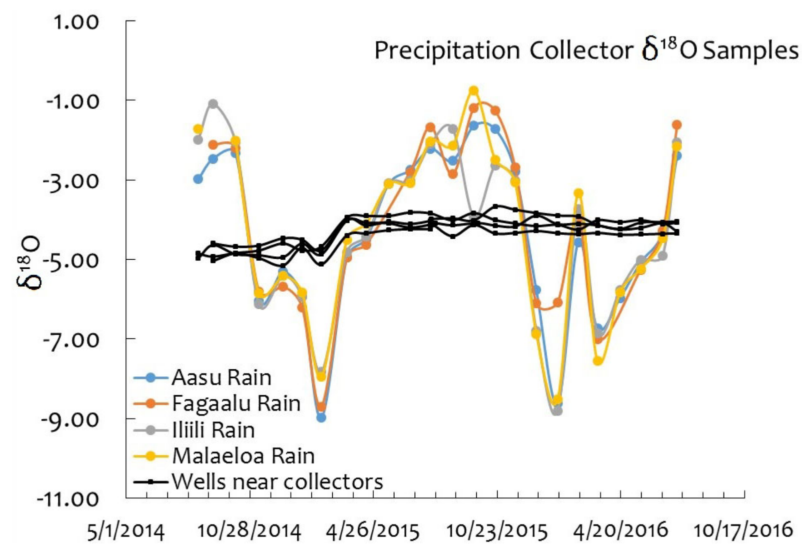

Figure 1. Water isotope values ($\delta^{18}O$) from monthly samples of rainfall and wells near to collectors.

Principal Findings and Significance

Monthly sampling of water isotopes in precipitation has shown distinct trends in seasonality, whereas groundwater samples lack this trend indicating that significant flushing of these aquifers does not occur on a seasonal basis (Fig. 1). Samples taken during a heavy rain

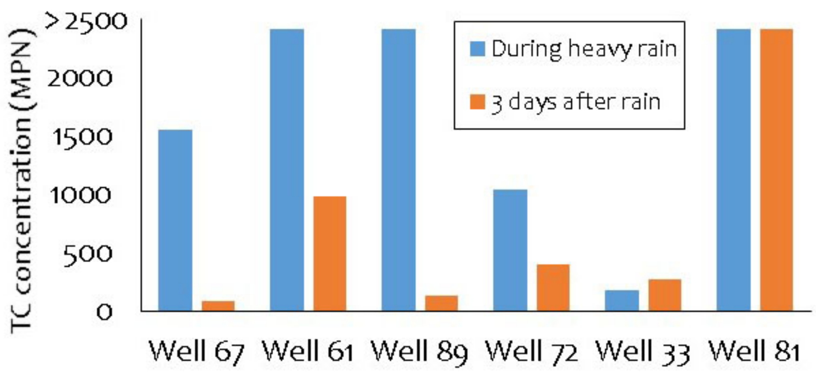

Figure 2. Total coliform concentrations in GUDI wells both during and after a heavy rain event.

event did show a small variation in water isotope values in GUDI wells only, allowing the potential for the assessment of a fraction of the recent recharge in the production water. We will use additional rain-event sampling to better constrain this quantification.

Bacteriological sampling clearly indicates a significant difference between GUDI wells, which consistently test positive for TC and *E. coli* vs. non-GUDI wells, which consistently test negative. The magnitude of TC and *E. coli* in GUDI wells also shows variation during and after heavy rain events (Fig. 2), which suggests that transport of bacteria from surface sources is linked to rain events, as opposed to being derived from in situ sources. This information helps constrain the rate of surface-to-groundwater transport and aquifer characteristics. Specifically, in GUDI wells groundwater must both (1) travel from surface sources rapidly enough to maintain viable bacterial populations, and (2) travel through aquifer material in the Tafuna and Malaeimi wellfield areas that does not provide sufficient physical filtration to remove bacteria.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Abstract planned for submission to 2017 Geological Society of America annual meeting in Seattle, WA, October 2017.

Publications Cited in Synopsis

American Samoa Environmental Protection Agency (ASEPA), 2016, "Territory of American Samoa integrated water quality monitoring and assessment report," AS-EPA 305[b] report, Pago Pago, AS. https://www.epa.as.gov/sites/default/files/documents/public_notice/2016%20AS%20Integrated%20Report%20for%20Public%20Notice%202016%200410%20FINAL.pdf (accessed October 2013).

American Samoa Power Authority (ASPA), 2012, "Groundwater under the direct influence of surface water: Well 70," ASPA report, Pago Pago, AS.

Entry, J.A., and N. Farmer, 2001, "Movement of coliform bacteria and nutrients in ground water flowing through basalt and sand aquifers," Journal of Environmental Quality, 30(5):1533–1539.

Foppen, J.W.A., and J.F. Schijven, 2006, "Evaluation of data from the literature on the transport and survival of *Escherichia coli* and thermotolerant coliforms in aquifers under saturated conditions," Water Research, 40(3):401–426.

Scholl, M.A., S.E. Ingebritsen, C.J. Janik, and J.P. Kauahikaua, 1996, "Use of precipitation and groundwater isotopes to interpret regional hydrology on a tropical volcanic island: Kilauea volcano area, Hawaii," Water Resources Research, 32(12):3525–3537.

Veselý, J., S.A. Norton, P. Skřivan, V. Majer, P. Kram, T. Navratil, and J.M. Kaste, 2002, "Environmental chemistry of beryllium," Reviews in Mineralogy and Geochemistry, 50(1):291–317.

Stream pesticide and nutrient loads from baseflow, surface runoff and sediment contributions on Tutuila Island, American Samoa

Basic Information

Title:	Stream pesticide and nutrient loads from baseflow, surface runoff and sediment contributions on Tutuila Island, American Samoa
Project Number:	2016AS455B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Models, Sediments, Water Quality
Descriptors:	None
Principal Investigators:	Henrieta Dulai

Publication

1. There are no publications for 2016.

Problem and Research Objectives

The project provides information on the distribution and transport of pollutants (nutrients, sediments, pesticides) in Fagaalu watershed, on the island of Tutuila in American Samoa (Figure 1). The watershed is heavily impacted by anthropogenic activity yielding high sediment and nutrient loads to the coastal reef. The project utilizes the combination of a watershed water budget model linked to a groundwater model along with pesticide, nutrient, and sediment measurements. The specific objectives are to calibrate the Soil and Water Assessment Tool (SWAT) model for sediment and pollutant loads and to determine the contribution of baseflow, surface runoff, and lateral flow to pollutant fluxes in Fagaalu Stream and coastline. In addition, a groundwater model (GMS) is used to simulate groundwater flowpaths to track subsurface nutrient and pesticide pathways. The models are complemented with and validated against in situ measurements of sediments, pesticides, groundwater level, and stream discharge.

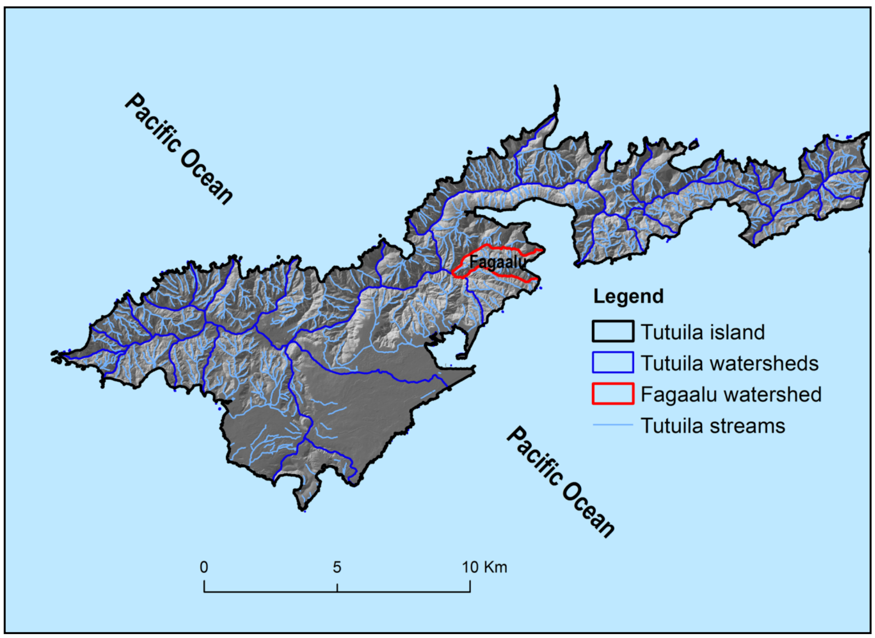

Figure 1. Fagaalu watershed, on the island of Tutuila, American Samoa.

Methodology

The suspended sediment (SS) modeling utilized a previously developed SWAT model for streamflow modeling of the Fagaalu watershed. The geo-spatial and hydro-meteorological data, including sediment gauging stations are shown in Figure 2. The model was developed, calibrated, and validated for the period 2005 to 2014. Following global parameter sensitivity analysis, the model was calibrated against observed SS by using the parameters to which the model showed high sensitivity. The model calibration and validation processes were enhanced by the availability of observed suspended sediment concentration and streamflow data (2012 to 2014) at Fagaalu's Dam and Lyndon Baines Johnson Tropical Medical Center (LBJ) stations,

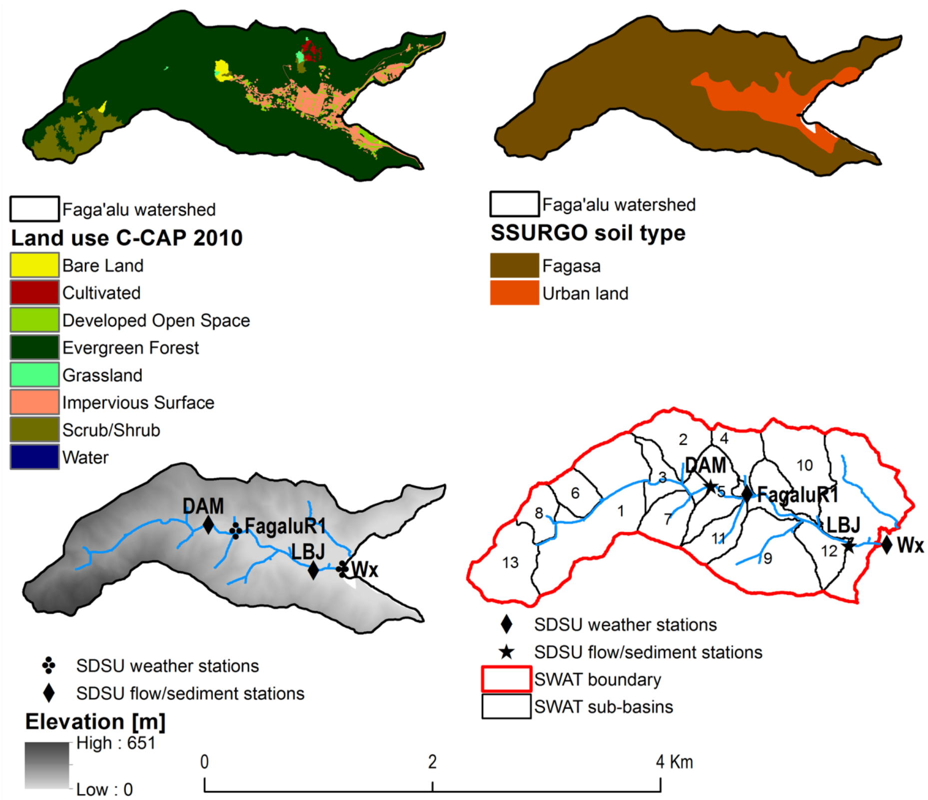

Figure 2. Geo-spatial and hydro-meteorological information for the Fagaalu watershed, including sediment gauging stations.

collected by collaborators from the Department of Geography, San Diego State University (SDSU) (A. Messina, 2016, personal communication). The effort also included data quality check and assurance. The model was then calibrated by using both manual and automatic calibration methods.

The GMS groundwater model used recharge determined by SWAT and was calibrated against the stream baseflow and groundwater level in the aquifer. A steady-state model was used to reconstruct the groundwater levels and flow paths. Flow paths were extracted for all groundwater samples collected across the watershed (well, river bank groundwater, coastal springs). The flow paths were then used to connect the measured glyphosate and nitrate concentrations to land use categories in the watershed to determine possible migration paths.

Principal Findings and Significance

Simulated SS fluxes suggest that SWAT generally well reproduced the daily temporal evolution of observed sediment loadings (Figure 3). While the SWAT well captured the observed sediment values at the upstream dam station, the model noticeably missed a few observed sediment loading values especially during the low to medium flow events at the downstream LBJ station (Figure 3a, c). Such characterizations could be related to human disturbance (or urbanization) at the lower part of the watershed, including quarry, road side and

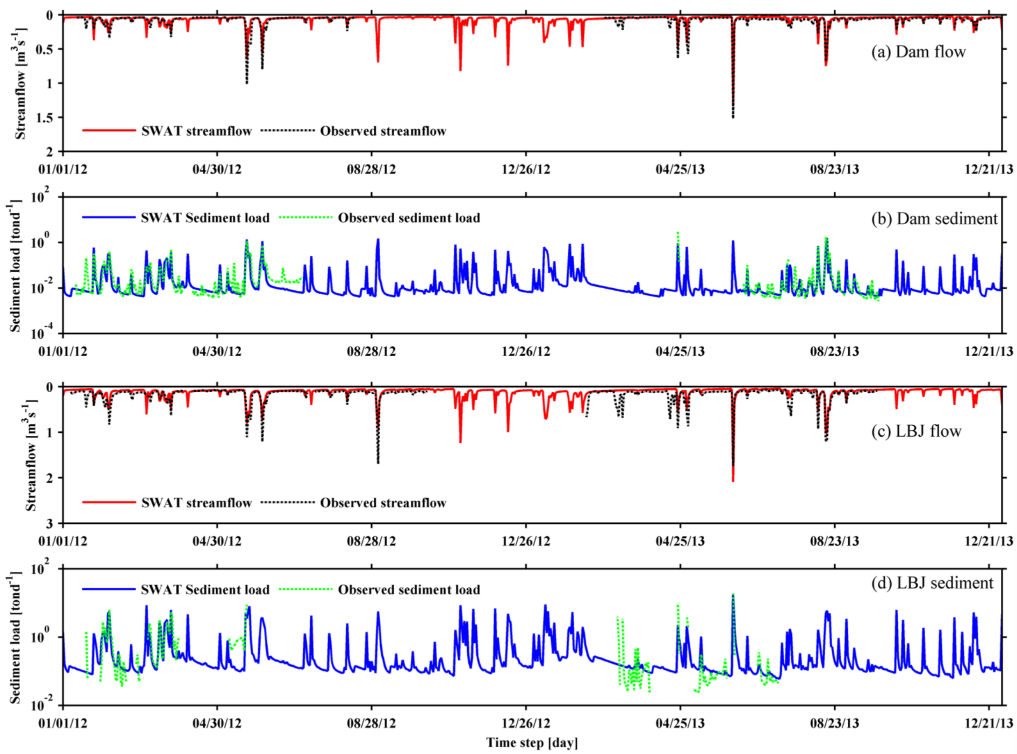

Figure 3. SWAT simulated and observed stream and sediment discharge at two locations in the Fagaalu watershed.

swimming activities, which cannot be easily represented in the model. Overall, findings indicate that while the upland forested watershed part of Fagaalu generates relatively lower amounts of suspended sediment fluxes, the lower, human-disturbed and urbanized part of the watershed produces a significant amount of sediment (Figure 3b, d), signifying the high impact of anthropogenic activities on sediment yield. This may cause considerable sediment loading and associated sediment-attached pollutant fluxes to the coastal reef. Chronic pesticide exposure even at low level may negatively affect the coastal ecosystem. The next phase of the project studies the contribution of different flow components to sediment loading to streams, and to evaluate the spatial variability of sediment yield. This study will also expand on the development model for both nutrient and pesticide fluxes.

In order to assess the groundwater's role as a pollution pathway, in situ samples were collected in the watershed. These show comparable levels of glyphosate and nitrate as found in other watersheds on the island with anthropogenic influences (Figure 4). However, all these are higher than the levels observed in pristine or less populated watersheds in the eastern and western parts of the island (all below detection limits of 0.04 ppb). We found that stream and stream bank groundwater had comparable levels of pesticides in both gaining and losing reaches of the stream. In addition, glyphosate was detected in both coastal springs. Groundwater is therefore a possible pathway for glyphosate migration. Groundwater flowpaths of all samples collected within the Fagaalu watershed were simulated using GMS (Figure 5). Our findings indicate that glyphosate concentrations in the watershed are low (in comparison to U.S. Environmental Protection Agency aquatic health benchmarks) but it is present in both ground and stream water. Transport via stream and groundwater flow is evident and will be

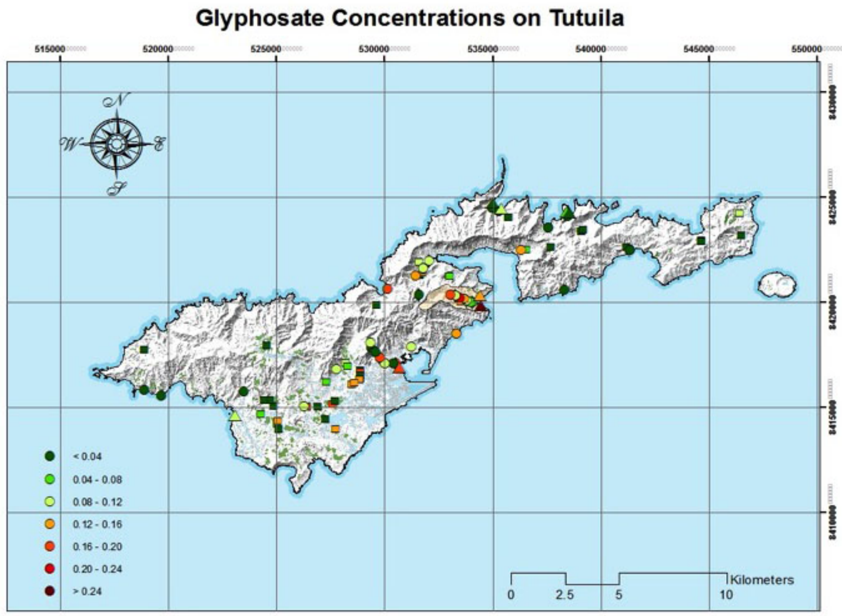

Figure 4. Glyphosate concentrations (ppb) in wells and streams on the island of Tutuila.

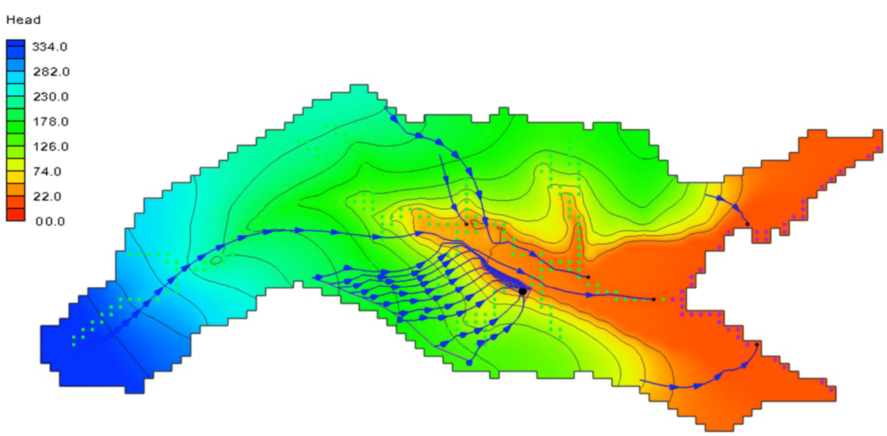

Figure 5. Groundwater level in Fagaalu watershed and groundwater flow paths of collected groundwater pesticide samples. Note: GMS MODFLOW and MODPATH were used to model the hydrogeology.

quantified in the next stage of the project. Higher pesticide levels correlate with shorter groundwater flow paths in the central part of the watershed and also in the coastal plain. Coastal springs had the highest concentrations of glyphosate that correlates with the most densely urbanized part of the watershed.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

None

Likely hotspots for algal blooms: A multi-dimensional analysis to evaluate seasonal impact of land-based sources of pollution on the health of American Samoa's coasts

Basic Information

Title:	Likely hotspots for algal blooms: A multi-dimensional analysis to evaluate seasonal impact of land-based sources of pollution on the health of American Samoa's coasts
Project Number:	2016AS456B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Rosanna Alegado, Celia Smith

Publications

1. Shuler, Chris, 2017, "Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa" Ph.D. Dissertation, Department of Geology and Geophyics, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Amato, D.W., C.M. Smith, C. Schuler, H. Duali, C.R. Glenn, V. Gibson, L. Baker, and R.A. Alegado, "Algal bioassays identify sources of land-based nutrient pollution in Hawaii and American Samoa," Oral Presentation in 13th International Coral Reef Symposium, Honolulu, HI, June 2016.
3. Shuler, C.K., D. Amato, V. Gibson, L. Baker, A.N. Olguin, H. Dulai, C.M. Smith, and R.A. Alegado, "Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa," Oral Presentation in American Society for Limnology and Oceanography Meeting, Honolulu, HI, February 2017.

Problem and Research Objectives

Recent hydrological studies have shown that land-use practices such as agricultural regimes significantly impact the state of coastal biological communities, via tainting submarine groundwater discharge (SGD), a vector for the delivery of anthropogenic nutrients to tropical reefs (Amato 2015, Amato et al. 2016). Sustainable land-use practices that put a premium on developing best practices for future farming and wastewater techniques, must consider the full ramifications of land-based sources of pollution, including severe ‘nutrification,’ an ecosystem level increase in nutrients that drives algal blooms (Van Houtan et al. 2010).

To build on a successful WRRC-funded field season on Tutuila (in July 2015) we examined seasonal variations, specifically the impact of the 2015 El Niño, on SGD on coastal biota. We used variations in nitrogen (N) (e.g., $\delta^{15}N$ and N% in deployed non-calcified algae), microbial community composition (assessed by next generation sequencing), and macrobenthic surveys at the impacted and reference sites as diagnostics for the impaired ecosystems. By coordinating genomic samplings for microbial diversity at the same sites where we examine the source (tissue analysis for $\delta^{15}N$) and the flux (tissue analysis for N%) of nitrogen, into those coastal sites, we expect to identify hot spots for likely shifts in the microbial community structure and benthic communities in potential impact sites and pristine coastal waters. This multi-year and continued multi-dimensional study will enable a better understanding of the SGD discharge and commensurate responses in coastal microbial communities that will aid resource managers in the ongoing monitoring and detection of wastewater in coastal communities.

Methodology

Using similar methods to those performed during our 2015 field season, we expanded and refined our sampling protocol in 2016 to target 5 algal species for collection and deployment (99 samples total). In 2016, 36 samples of *Hypnea pannosa* were deployed in cages as a bioassay at our four study locations. Including both field seasons, nearly 250 algal samples (representing 15 species) have been collected and tested for tissue analysis of $\delta^{15}N$ and N%. A total of 56 marine surface and coastal spring water samples were collected and submitted for analysis of inorganic nutrients in 2016. In addition to surveying microbial communities in the water column (0.4-µm filters) and benthic microbial biofilm by deployment of horizontal glass slides (as in 2015), we deployed 200 vertical glass slides for nine days to survey more mature biofilm communities by next generation sequencing and electron microscopy. Microbial community analysis next generation sequencing is pending.

Principal Findings and Significance

Thus far, the 2016 data is consistent with the 2015 data set. Comparisons among the four principal locations using algal tissue $\delta^{15}N$ indicated nearly identical trends to our 2015 data set. The average algal tissue $\delta^{15}N$ values were highest at the extensively impacted locations (Fagaalu and Pala Lagoon) and lowest at the minimally impacted locations (Vatia and Oa), which indicated wastewater as a likely source of N to the coastal waters of Fagaalu and Pala Lagoons.

The deployment of *Hypnea pannosa* in 2016 enabled a more robust comparison of algal tissue indicators among the four locations. Not surprisingly, the results from deployed *H. pannosa* showed very similar trends among the locations to the average values of collected samples (all species collected *in situ*) from both 2015 and 2016, indicating that samples with elevated $\delta^{15}N$ values generally have more N stored in their tissues. Therefore, coastal reef areas where wastewater is a source of N may have higher concentrations of biologically available N in the water column. This hypothesis was supported by our coastal water nutrient results from both 2015 and 2016. Similar to our 2015 data set, both water samples and algal samples detected a "hot spot" for wastewater derived N in Vatia (categorized as a minimally impacted location) near a significant coastal spring.

Though we anticipated inter-annual variations in the parameters we measured due to El Niño effects, data from 2015 and 2016 show similar trends across the locations. We hypothesize that correspondence between field seasons reflected mild regional effects in American Samoa as compared to the other Pacific regions between Summer 2015 and Summer 2016. Algal bioassays indicated that coastal water chemistry at our study locations did not change over the year. We anticipate a similar result will be visible in the microbial community data set (results pending). Clear linkages between land use and coastal water quality are evident when the extensively impacted regions are compared to minimally impacted regions. In addition, we anticipate that water chemistry at the study locations in American Samoa will be closely linked with human density and the N input from piggeries and other agricultural practices.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Amato, D.W., C. Schuler, V. Gibson, Baker, R.A. Alegado, C.R. Glenn, H. Duali, and C.M. Smith, "Algal bioassays show land-based, anthropogenic nitrogen is delivered to reef biota by groundwater in Hawaii and American Samoa." (in preparation)

Amato, D.W., C. Schuler, C.R. Glenn, V. Gibson, N. Olguin, C.M. Smith, R. Alegado, C. Nelson, and T. Oliver, "Assessment of land-based sources of pollution on coral reefs of Tutuila, American Samoa," Presentation at the American Samoa Environmental Protection Agency, Pago Pago, American Samoa, August 2016.

Shuler, C.K., D. Amato, V. Gibson, L. Baker, A.N. Olguin, H. Dulai, C.M. Smith, and R.A. Alegado, "Assessment of terrigenous nutrient loading to coastal ecosystems on Tutuila, American Samoa." (in preparation)

Publications Cited in Synopsis

Amato, D.W., 2015, "Ecophysiological responses of macroalgae to submarine groundwater discharge in Hawaii*,"* Ph.D. dissertation, University of Hawaii at Manoa, Honolulu.

Amato, D.W., J.M. Bishop, C.R. Glenn, H. Dulai, and C.M. Smith, 2016, “Impact of submarine groundwater discharge on marine water quality and reef biota of Maui,” PLoS One, 11(11):e0165825. https://doi.org/10.1371/journal.pone.0165825.

Van Houtan, K., S. Hargrove, and G.H. Balazs, 2010, “Land use, macroalgae, and a tumor-forming disease in marine turtles,” PLoS One, 5(9):e12900. https://doi.org/10.1371/journal.pone.0012900.

Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa

Basic Information

Title:	Real-time Optimization of Irrigation Scheduling for Farmlands in American Samoa
Project Number:	2016AS457B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	
Research Category:	Climate and Hydrologic Processes
Focus Category:	Irrigation, Agriculture, Hydrology
Descriptors:	None
Principal Investigators:	Sayed Bateni

Publication

1. There are no publications for 2016.

Problem and Research Objectives

In some regions of American Samoa, water is by far the major constraint to crop production. Even areas with abundant rainfall experience a high seasonal variability that does not maintain adequate water for the crops throughout the year (Yu et al. 1997). High temperature and evapotranspiration rate, in combination with limited water storage capacity of soil, also reduce water availability for crops (Izuka et al. 2005). On the other hand, the limited supply of water is subject to ever increasing demands. American Samoa (like many other places) is growing in population and it is important to implement water conservation measures to stretch supplies as long as possible. One of the easiest and most effective ways to conserve the water resources in American Samoa is to design an optimal irrigation scheduling.

A robust method (based on the water budget equation) is proposed in this project to efficiently schedule irrigation in the farmlands of American Samoa. The irrigation scheduling algorithm uses weather station-derived evapotranspiration, soil water holding capacity, and the application rate of the irrigation system to estimate the appropriate irrigation interval and volume of water to apply in order to maximize growth and minimize losses to leaching. This approach is based on the crop evapotranspiration (ET_0). Estimation of ET_0 determines whether there is inadequate water that can decrease yields or if there is excessive water application that can result in water logging or leaching of nitrates below the root zone. Thus, estimation of ET_0 is required for effective irrigation water management.

Methodology

Genetic Expression Programming (GEP) is a progressive algorithm that continuously adapts to determine the relationship between a given set of inputs and output(s) (Ferreira 2001). GEP utilizes evolving computer programs (expression trees) of different sizes that are encoded with a finite linear string of input data (chromosomes). A final expression tree is produced consisting of mathematical expressions and polynomials (Guven and Gunal 2008).

GEP begins with a random generation of chromosomes for a specific program. These chromosomes are made up of genes (finite linear string containing input data) that are linked by arithmetic operators (e.g., +, -, ×, /) (Oltean and Grosan 2003). GEP genes are made up of two parts: the head and the tail. The head consists of both terminal symbols (independent variables) and functional symbols (e.g., Arctan). The tail only consists of terminal symbols and is calculated as follows:

$$t = (n\text{-}1)h + 1 \qquad (1)$$

where t is the tail length, n is the amount of arguments in the functions, and h is the head length chosen by the user.

After the chromosomes are generated and used in the program, the accuracy of the program is evaluated using a fitness function (e.g., Root Mean Square Error [*RMSE*]) and fitness cases (i.e., the training data). The fitness function compares the dependent variable (e.g., ET_0) from the given training dataset to the values created by the program. The program will either be selected or rejected based upon its ability to simulate the dependent variable of the dataset. If the program is selected, then it is replicated and further improved through chromosome modifications. The chromosomes are modified through replication, mutation, transposition, and crossover (i.e., recombination) (Ferreira 2001).

Principal Findings and Significance

Daily climatic data from January 1, 2000 to December 31, 2008 was collected from eight weather stations in the coastal regions of Iran. The recorded data were daily average relative humidity (RH_{mean}), daily mean wind speed at a reference height of 2 meters (W_s), daily mean air temperatures (T_{mean}), and incoming solar radiation (R_s). The hydrological data and the corresponding calculated ET_0 values from the Penman-Monteith equation were used to train and test the GEP model.

Daily climatic data from January 1, 2015 to December 31, 2015 was collected from fourteen California Irrigation Management Information System (CIMIS) weather stations. The hydrological data and the corresponding calculated ET_0 were used to validate the developed GEP model.

W_s, RH_{mean}, T_{mean}, and R_s were used in the GEP model to generate an equation to estimate ET_0:

$$ET_0 = \frac{\left(W_s + (W_s + 3.66)\right) + \left(\left(\frac{RH_{mean}}{9.42} - R_s\right)\right.}{-3.66} + \arctan\left(\sqrt{\exp\left(\left(\frac{RH_{mean}}{4.15}\right)^2 - \left((W_s + 4.15) + 4.15\right)\right)}\right) + W_s - \cos\left(\arctan(R_s - 9.23) - \frac{T_{mean}}{9.82}\right) \tag{2}$$

Two weather stations were purchased from the Onset company, and sent to American Samoa. These two stations will measure hydrological variables (e.g., incoming solar radiation, wind speed, air humidity, etc.) at the cooperative farmlands. The measured hydrological data will be used in generated GEP equation to estimate evapotranspiration in the cooperative farmlands of Guam.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

UH Water Resources Research Center received nearly $1M for a water sustainability project from the US Department of Agriculture. Funding will be used to conduct research on developing optimal irrigation strategies in farmlands throughout Hawaii, Guam, and American Samoa (http://www.hawaii.edu/news/2016/09/08/uh-water-resources-research-center-receives-nearly-1m-for-water-sustainability-project/).

Publications Cited in Synopsis

Ferreira, C., 2001, "Gene Expression Programming: A New Adaptive Algorithm for Solving Problems," Complex Systems, 13(2):87–129.

Guven, A., and M. Gunal, 2008, "Genetic programming for prediction of local scour

downstream of grade-control structures," Journal of Irrigation and Drainage Engineering, 134(2):241–249.
Izuka, S.K., T.W. Giambelluca, and M.A. Nullet, 2005, "Potential evapotranspiration on Tutuila, American Samoa," US Geological Survey Scientific Investigations Report No. 2005-5200. Retrieved from http://pubs.usgs.gov/sir/2005/5200/
Oltean, M., and C. Grosan, 2003, "A Comparison of Several Linear Genetic Programming Techniques," Complex Systems, 14:285–313.
Yu, Z-.P., P-.S. Chu, and T. Schroeder, 1997, "Predictive skills of seasonal to annual rainfall variations in the U.S. affiliated Pacific Islands: Canonical Correlation Analysis and Multivariate Principal Component Regression Approaches."

Assessment of Groundwater Availability in the Volcanic Rock Aquifers of Hawaii-modification

Basic Information

Title:	Assessment of Groundwater Availability in the Volcanic Rock Aquifers of Hawaii-modification
Project Number:	2015HI465S
USGS Grant Number:	
Sponsoring Agency:	U.S. Geological Survey
Start Date:	9/1/2016
End Date:	12/31/2016
Funding Source:	104S
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Aly I El-Kadi

Publications

1. Izuka, S.K., J.A. Engott, M. Bassiouni, A.G. Johnson, L.D. Miller, K. Rotzoll, and A. Mair, 2016, “Hawai‘i volcanic aquifers—Hydrogeology, water budgets, and conceptual models,” USGS Scientific Investigations Report, 2015–5164, 158 p.
2. Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, “Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii,” Abstract H31G-1506, presented at 2015 Fall Meeting, AGU, San Francisco, CA, December 14–18.
3. Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, “Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii,” The Second Conference on Water Resource Sustainability Issues on Tropical Islands, Honolulu, HI, December 1–3.
4. Izuka, S.K., K. Rotzoll, and T. Nishikawa, 2016, “Challenges of modeling groundwater in the volcanic island aquifers,” Poster presented at 2016 U.S. Geological Survey National Groundwater Workshop, Reno, NV, August 29–September 2, 2016.
5. Rotzoll, K., and S.K. Izuka, 2017, “Impacts of groundwater withdrawals in Hawaii,” Presented at 2017 Geological Society of America, Cordilleran Section—113th Annual Meeting, Honolulu, HI, May 23–25, 2017.
6. Rotzoll, K., and S.K. Izuka, 2017, “Modeling effects of historical groundwater development on water resources of Hawaii,” Presented at 2017 Pacific Water Conference—4th Annual Conference, American Water Works Association, Honolulu, HI, February 14–16, 2017.

Problem and Research Objectives

The availability of fresh groundwater for human use is limited by whether the impacts of withdrawals are deemed acceptable by community stakeholders or water-resource managers. Quantifying the island-wide hydrologic impacts of withdrawal—saltwater intrusion, water-table decline, and reduction of groundwater discharge to streams, nearshore environments and downgradient groundwater bodies—is thus important to assess fresh groundwater availability. The scope of work is a numerical modeling analysis of newly available recharge and hydrogeologic information for the islands of Kauai, Oahu, and Maui (Izuka et al. 2016) to (1) improve understanding of the most developed regional groundwater-flow systems in the main islands of Hawaii, (2) update knowledge of the availability of groundwater resources, and (3) provide insight into the impacts of human activity and climate change on groundwater resources.

Methodology

Groundwater-flow models of Kauai, Oahu, and Maui were constructed using MODFLOW 2005 with the Seawater-Intrusion Package (SWI2), which simulates the transition between saltwater and freshwater as a sharp interface (Bakker et al. 2013). Consistent model construction, calibration, and analysis were streamlined using Python scripts (Bakker et al. 2016).

Principal Findings and Significance

Results of simulating historical withdrawals from Hawaii's volcanic aquifers show that the types and magnitudes of impacts vary among hydrogeologic settings. In high-permeability freshwater-lens aquifers, saltwater intrusion and reductions in coastal groundwater discharge have been the principal consequences of withdrawals. In dike-impounded groundwater and thickly saturated low-permeability aquifers, reduced groundwater discharge to streams, water-table decline, or reduced flows to adjacent freshwater-lens aquifers can be unacceptable consequences that limit groundwater availability. The numerical models are used to quantify and delineate the spatial distribution of these impacts for the three islands. The models can also be used to examine how anticipated changes in groundwater recharge and withdrawals will affect groundwater availability in the future.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Izuka, S.K., J.A. Engott, M. Bassiouni, A.G. Johnson, L.D. Miller, K. Rotzoll, and A. Mair, 2016, "Hawaii volcanic aquifers—Hydrogeology, water budgets, and conceptual models," USGS Scientific Investigations Report, 2015−5164, 158 p.

Izuka, S.K., K. Rotzoll, and T. Nishikawa, 2016, “Challenges of modeling groundwater in the volcanic island aquifers,” Poster presented at 2016 U.S. Geological Survey National Groundwater Workshop, Reno, NV, August 29–September 2, 2016.

Rotzoll, K., and S.K. Izuka, 2017, “Impacts of groundwater withdrawals in Hawaii,” Presented at 2017 Geological Society of America, Cordilleran Section—113th Annual Meeting, Honolulu, HI, May 23–25, 2017.

Rotzoll, K., and S.K. Izuka, 2017, “Modeling effects of historical groundwater development on water resources of Hawaii,” Presented at 2017 Pacific Water Conference—4th Annual Conference, American Water Works Association, Honolulu, HI, February 14–16, 2017.

Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2016, “Quantifying effects of humans and climate on groundwater resources of Hawaii through sharp-interface modeling,” Abstract H23E-1594, Poster presented at 2016 American Geophysical Union Fall Meeting, San Francisco, CA, December 12–16, 2016.

Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, “Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii,” Abstract H31G-1506, Poster presented at 2015 American Geophysical Union Fall Meeting, San Francisco, CA, December 14–18, 2015.

Rotzoll, K., S.K. Izuka, T. Nishikawa, M.N. Fienen, and A.I. El-Kadi, 2015, “Quantifying effects of humans and climate on groundwater resources through modeling of volcanic-rock aquifers of Hawaii,” Presented at The Second Conference on Water Resource Sustainability Issues on Tropical Islands, Honolulu, HI, December 1–3, 2015.

Publications Cited in Synopsis

Bakker, M., F. Schaars, J.D. Hughes, C.D. Langevin, and A.M. Dausman, 2013, “Documentation of the seawater intrusion (SWI2) package for MODFLOW,” U.S. Geological Survey Techniques and Methods book 6, chap. A46, 47 p.

Bakker, M., V. Post, C.D. Langevin, J.D. Hughes, J.T. White, J.J. Starn, and M.N. Fienen, 2016, “Scripting MODFLOW model development using Python and FloPy,” Groundwater, 54(5):733–739. doi:10.1111/gwat.12413.

Izuka, S.K., Engott, J.A., Bassiouni, M., Johnson, A.G., Miller, L.D., Rotzoll, K., and Mair, A., 2016, “Volcanic aquifers of Hawaiʻi—hydrogeology, water budgets, and conceptual models,” U.S. Geological Survey Scientific Investigations Report 2015-5164, 158 p.

Evaluating Student Training and STEM Workforce Development at the National Institutes for Water Resources (NIWR)

Basic Information

Title:	Evaluating Student Training and STEM Workforce Development at the National Institutes for Water Resources (NIWR)
Project Number:	2015HI478S
USGS Grant Number:	
Sponsoring Agency:	INTERIOR, USGS
Start Date:	8/1/2016
End Date:	7/31/2017
Funding Source:	104S
Congressional District:	
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Darren T. Lerner

Publications

1. Brazil, L.E., 2017, “The water resource workforce: Impressions from the nonprofit sector,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
2. Donohue, M.J., E.A. Greene, D.T. Lerner, and P. Moravcik, 2017, “Students, fellows and Feds: Training the next generation of water resource professionals,” Special Session at the University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
3. Donohue, M.J., E.A. Greene, P. Moravcik, and D.T. Lerner, 2017, “Evaluating student training and STEM workforce development at the National Institutes for Water Resources (NIWR),” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
4. Donohue, M.J., D.T. Lerner, and E. Greene, “Student training and workforce development,” A white paper on the U.S. Geological Survey National Institutes for water resources role and capabilities. (in preparation)
5. Greene, E., 2017, “The United States Geological Survey (USGS) workforce: Today and tomorrow,” Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
6. Lerner, D.T., 2016, “Alumni/workforce development an under-used metric?” Presented at 2016 NIWR Annual Meeting, February 8–10, 2016, The Hotel George, Washington, D.C.
7. Lerner, D.T., 2016, “NIWR human resource tracking effort,” Presented at Sea Grant Association Biannual Meeting, October 8–9, 2016. Newport, RI.

8. Lerner, D.T., and M.J. Donohue, 2017, "NIWR student training & workforce development," Presented at National Institutes for Water Resources Annual Meeting, February 27–March 1, 2017, Phoenix Park Hotel, Washington, D.C.
9. Snow, E., 2017, "How the USGS engages with universities to provide research and training opportunities for students," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.
10. Webb, C., 2017, "How embracing diversity improves results: Sharing experiences from a 20 year career in a water utility," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Problem and Research Objectives

Student training and workforce development is a key academic, social and economic metric valued by society including: industry, universities and colleges, the US Congress, the US Office of Management and Budget (OMB), and the United States Geological Survey (USGS), among others.

A major component of the Water Resources Research Act (WRRA) is to provide for training of the next generation of scientists and engineers through the USGS National Institutes for Water Resources (NIWR). The National Institutes for Water Resources has a demonstrated record in this area having trained 25,000 students in its first 50 years while currently supporting or training approximately 1,000 students annually at more than 150 universities, as well as mentoring USGS interns. However, the compilation, analyses and presentation of these data to better understand and document NIWR's contributions to education and workforce development have been modest, to date. Further exploration on the workforce placement of students supported by NIWR will clarify the value of this investment to society.

This research investigates the education and training activities and outcomes of NIWR through the WRRA and the role of these efforts in our nation's science, technology, engineering and mathematics (STEM) workforce. Findings will inform understanding of NIWR's student support, and the role this support plays in training the next generation of federal water scientists and managers.

Research Objectives

A. Summary of overview data via NIWR.net, the national NIWR reporting database, in collaboration with USGS and NIWR.
B. Initiate summary of additional state program data on students supported through engagement with WRRA/NIWR funded state water institutes.
C. Gap analysis generated for data opportunities and needs, emerging from the direct involvement of USGS and state water institute directors.

Methodology

Compilation, synthesis and analyses of archived NIWR data on students supported at the state and federal level and gap analysis of alumni data opportunities and needs.

In collaboration with the USGS and NIWR, data were extracted from the national NIWR reporting database (NIWR.net) on students supported by state water institutes funded via WRRA/NIWR. Data were compiled for each state water institute by year, student category, and funding instrument. Student categories included undergraduates, Master's graduates, doctoral graduates, as well as post-doctoral associates. Because individual state water institutes may support an individual student over one or several years of training, student support for individual state water institutes is reported as student support years when analysis includes more than one year. Funding categories examined included base grants, National Competitive Grant Program funding (NGCP), NIWR-USGS internships and supplemental awards. Years examined included the most recent fifteen-year period (2000–2015). State data were also pooled to provide a compilation of students supported by student category and funding instrument by year for the federal NIWR program investment as a whole.

In collaboration with the USGS and University of Hawaii Water Resources Research Center Interim Director, we engaged with leadership and other faculty at other state water institutes to document and summarize the extent of student data collected, how such data were obtained, and the current use and any proposed future use of these data. An online survey was developed and sent to each state water institute to investigate elements of student data collection and archival and attitudes toward student support relative to the missions of state water institutes as well as NIWR. Survey questions included inquiries on the extent of personal information currently collected on students e.g., name, degree earned, post-degree placement, etc., the use and presentation of these data e.g., development/donor activities, inreach to universities and the USGS, website and social media engagement, and other parameters.

In collaboration with USGS and NIWR, utilization of the above activities as well as further direct engagement of the USGS and state water institute directors was conducted to generate a gap analysis of alumni data opportunities and needs.

Principal Findings and Significance

A. In collaboration with USGS and NIWR, a summary of data on students supported by state water institutes from 2000 to 2015 was completed.
   1. A total of 10,853 students were supported by state water institutes from 2000 to 2015.
   2. The average number of students supported by state water institutes (pooled) by year approached 700 and increased overall by about 10 students/year from 2000 to 2015 (average 678 ± 83 SD, range = 518 to 788, $y = 10.204x + 591.58$).
   3. The average number of student support years by individual state water institutes for the 15-year interval from 2000 to 2015 was highly variable by institute, with an average of 201 ± 102 SD (range = 76 to 646; median = 175). Because individual state water institutes may support an individual student over one or several years of training, student support for individual state water institutes is reported as student support years when analysis includes more than one year.

B. A summary of additional state program data was obtained via survey engagement with WRRA/NIWR funded state water institutes.
   1. Student or fellow support/training was reported to be “very important” to the mission of both state water institutes and NIWR (80% of survey respondents and 87% of survey respondents, respectively).
   2. The most common use of student support data by state water institutes is required reporting, and nearly one-half (49%) of programs do not use these data for any other purpose.
   3. Other uses of student support data reported by state water institutes include institute promotion (44%), website and social media engagement (40%), and development/donor activities (16%). Multiple responses per survey question possible per institute. Number of state water institutes reporting: N = 45.

4. The most common way state water institutes manage data on students or fellows is original files submitted by researchers and other faculty with 71% of institutes citing this practice. Slightly over one-half of institutes (53%) use NIWR.net, the federal reporting database.

C. A white paper is in preparation that will include gap analysis for data opportunities and needs emerging from the direct involvement of USGS and state water institute directors.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Brazil, L.E., 2017, "The water resource workforce: Impressions from the nonprofit sector," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Donohue, M.J., E.A. Greene, D.T. Lerner, and P. Moravcik, 2017, "Students, fellows and Feds: Training the next generation of water resource professionals," Special Session at the University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Donohue, M.J., E.A. Greene, P. Moravcik, and D.T. Lerner, 2017, "Evaluating student training and STEM workforce development at the National Institutes for Water Resources (NIWR)," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Donohue, M.J., D.T. Lerner, and E. Greene, "Student training and workforce development," A white paper on the U.S. Geological Survey National Institutes for water resources role and capabilities." (in preparation)

Greene, E., 2017, "The United States Geological Survey (USGS) workforce: Today and tomorrow," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Lerner, D.T., 2016, "Alumni/workforce development an under-used metric?" Presented at 2016 NIWR Annual Meeting, February 8–10, 2016, The Hotel George, Washington, D.C.

Lerner, D.T., 2016, "NIWR human resource tracking effort," Presented at Sea Grant Association Biannual Meeting, October 8–9, 2016. Newport, RI.

Lerner, D.T., and M.J. Donohue, 2017, "NIWR student training & workforce development," Presented at 2017 NIWR Annual Meeting, February 27–March 1, 2017, Phoenix Park Hotel, Washington, D.C.

Snow, E., 2017, "How the USGS engages with universities to provide research and training opportunities for students," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Webb, C., 2017, "How embracing diversity improves results: Sharing experiences from a 20 year career in a water utility," Presented at University Council on Water Resources (UCOWR)/National Institutes of Water Resources (NIWR) Conference: Water in a Changing Environment, June 13–15, 2017, Fort Collins, CO.

Understanding the hydrology of a rainforest watershed in Hawaii

Basic Information

Title:	Understanding the hydrology of a rainforest watershed in Hawaii
Project Number:	2016HI459B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Surface Water, Ecology
Descriptors:	None
Principal Investigators:	YinPhan Tsang, Carl Evensen

Publications

1. Huang Y.-F., Tsang, Y.-P., and C. Evensen, "Different approaches of streamflow measurement for rainforest watersheds in Hawaii." (in preparation)
2. Tsang, Y.-P., A. Strauch, A. Lynch, and D. Infante. 2016. "The natural flow regime of Hawaii streams." Poster presented in 2016 American Geophysical Union, San Francisco, CA, December 12–16, 2016.

Problem and Research Objectives

To further our knowledge of a rainforest watershed in Hawaii, this project proposes to study the rainfall runoff process in a rainforest watershed in Hawaii. At least one graduate student will be funded and trained in watershed hydrology through this project. We expect to promote a healthy watershed and water resources management, both in terrestrial and fluvial ecosystems. The focus of this project is the Manoa Watershed. We also included Waiakeakua Stream, a tributary of Manoa Stream, and Palolo Stream to conduct hydrologic modeling for Manoa-Palolo Watershed.

The goal of this project is to study an existing rainforest watershed by establishing a stream monitoring system. The objectives of this study include:

1. Setting up two continuous stream monitoring stations (including discharge, temperature, and electric conductivity) at Aihualama Stream, which flows through the watershed at Lyon Arboretum—one at the watershed outlet (in Year 1), and the second at the mid-watershed segment (in Year 2).
2. Understanding the typical flow response to precipitation, and describing the main factors that drive the streamflow at a forest watershed.
3. Calibrating a hydrological model with streamflow data to describe the hydrology of the rainforest watershed.

Methodology

Equipment

The In-Situ Level TROLL 500 Water Level Logger (LevelTroll) and YSI 6600 Multi-Parameter Water Quality Sonde (YSI) were used for monitoring stream stage and water quality (i.e., temperature, conductivity, salinity, total dissolved solid, turbidity, dissolved oxygen, and pH). InteleCells (Intelesense Inc.) was selected for telemetry (at a reasonable price) and has been used in Hawaii for other stream monitoring. The Intelesense remote connector included two InteleCells, one was an in-situ connecting with LevelTroll and YSI, and the other was a gateway for connecting the internet for real-time data.

Site Location Selection

The stream monitor well (pipe) had to be embedded in an immovable rock and submerged by stream water (ideally in a stable pool). We conducted several site visits along the streams and consulted with the director and ground manager at Lyon Arboretum.

Flow Measurement

To build a rating curve, we used two methods to measure the stream discharge: the velocity cross-section area method with a current-meter (SonTek FlowTracker Handheld-ADV® (Acoustic Doppler Velocimeter) and the salt injection method (Moore 2003, 2005). Measuring the velocity cross-section with the current-meter was convenient and widely used in the field (Young 1950). However, the mountainous (headwater) streams are usually small with shallow depth of streamflow, which could lead to measurement errors. Two flow measurement methods were used to prevent potential inaccuracies due to low-flow conditions: (1) the

Acoustic Doppler probe, which has a minimum depth of 0.02 m; and (2) salt injection, which required preparation but is accurate and not limited by the size of the stream (Moore 2003). Both methods were compared to ensure the accuracy of the flow measurement for building the rating curve.

Problems/Challenge

The first stream monitoring station at Lyon Arboretum was successfully installed, but has not been adjusted to provide real-time data. As planned, the monitoring telemetry would depend on the internet connection available at the arboretum, which is currently obsolete and unstable. This should be rectified shortly when the University of Hawaii Information Technology Services and the Lyon Arboretum staff complete the process of updating and replacing the internet and cable network. Once that is accomplished, the real-time monitoring gauges with be tested.

Principal Findings and Significance

1. Watershed visits to identify locations for setting stream monitoring gauges.

   We consulted with the director and ground manager at Lyon Arboretum, and had multiple site visits along the streams. We selected a monitoring location that had a stable large boulder and deep pool. Also, to measure the streamflow, a stream channel was selected about 10-m upstream from the monitoring location (where it is straight and less turbulent) (Figure 1).

Figure 1. Locating stream monitoring gauge sites in the watershed. (a) Co-Principal Investigator C. Evensen showing the diversion for the loi (taro farm) on the right bank of the Aihualama Stream; (b) River bank in wet conditions; (c) The streamflow is turbulent most of time due to the rocky streambed; and (d) Leaf and branch litters are common along the Aihualama Stream.

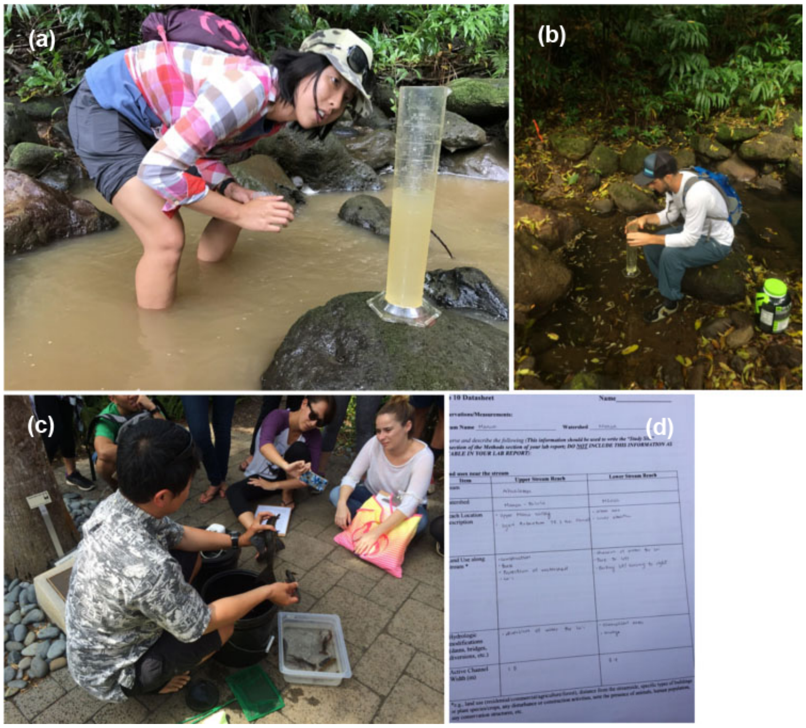

Figure 2. Graduate and undergraduate student training. (a) Graduate student Yu-Fen Huang monitoring streamflow using the salt injection method; (b) Student Brendan Martin learning how to measure the flow rate using the salt injection method; (c) Stream biologist Cory Yap showing stream fauna to NREM 301+L Natural Resources Management and Laboratory class; and (d) Example of a survey handout.

2. Training graduate and undergraduate students.

   Beginning in the Fall of 2016, graduate student Yu-Fen Huang was the main trainee of this project. Two other graduate students, Brendan Martin and Kelly-Rose Lariosa, were also trained in flow measurement. In addition, two courses taught by Principal Investigator Y.-P. Tsang (Natural Resources Management and Laboratory, NREM 301+L; Watershed Hydrology, NREM 662) were able to use the site for practical experience for the students in laboratory training and education (Figure 2).

3. Identifying weather stations and understanding the weather patterns

   The distribution of rainfall gradient varies from high in the mountains to low towards the ocean (Giambelluca et al. 2013). The Waihi sub-watershed, where our watershed study is located, is the wettest area in the Manoa-Palolo Watershed. A high rainfall spatial-gradient (~650 mm/km from mountain to ocean) in the Manoa-Palolo Watershed (Figure 3) implies potential challenges in the Soil and Water Assessment Tool (SWAT) modeling.

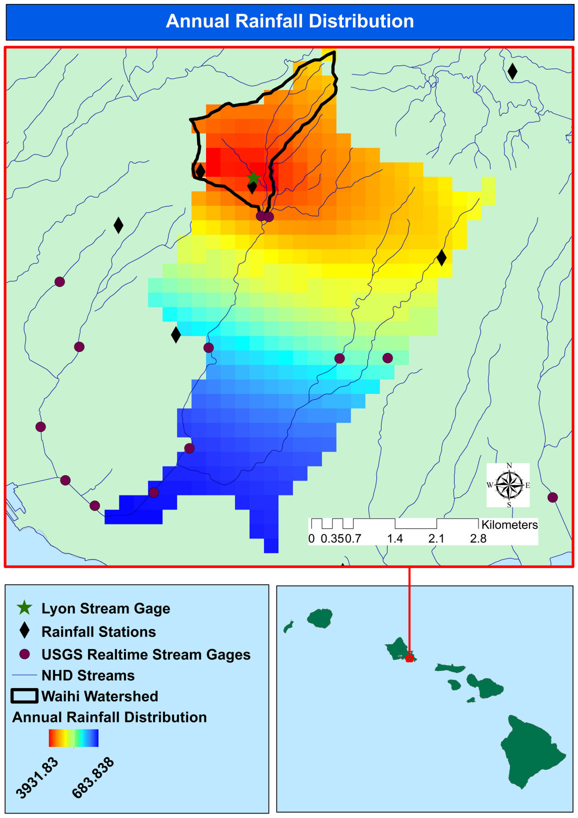

Figure 3. Annual rainfall distribution (Giambelluca et al. 2013) of Manoa-Palolo Watershed with proposed stream monitor (green star), rainfall stations (blue diamonds), and USGS stream gauges (red circles). Note: The blue lines = streams based on the USGS National Hydrography Dataset; bold black line = Waihi sub-watershed.

4. Stream monitoring.

   The Aihualama Stream monitor at Lyon Arboretum was successfully installed on 19 September 2016 (Figure 4). The first stream gauge with in-situ InteleCell was installed at 21.88408°N, 157.80179°W, which is within the radius distance to effectively connect to the gateway InteleCell at the Lyon Arboretum greenhouse. Consequently, the monitoring station started collecting data for both stream stage and water quality.

   The data are updated online:
   https://www.intelesense.net/data/intelecell/0000001100060005/t:water

5. Building the rating curve.

   The rating curve at Aihualama Stream for our first stream monitoring station had been built by 11 measurements using the velocity cross-section area method, and seven measurements using the salt injection method (Figure 5). The rating curve shows slight differences between the methods in low-flow conditions; however, the two rating curves showed more differences when the stream stage is greater than 0.55 m. We need to collect more high-flow measurements to increase our confidence in the rating curve, especially for the salt injection method. The streamflow was estimated with the rating curve of the velocity cross-section area method, because it included the high-flow measurements.

Figure 4. Setting-up a stream monitoring station. (a) Installing a gateway InteleCell in the Lyon Arboretum greenhouse; (b) Setting-up the upstream gauge in Aihualama Stream; and (c) Completing the in-situ InteleCell.

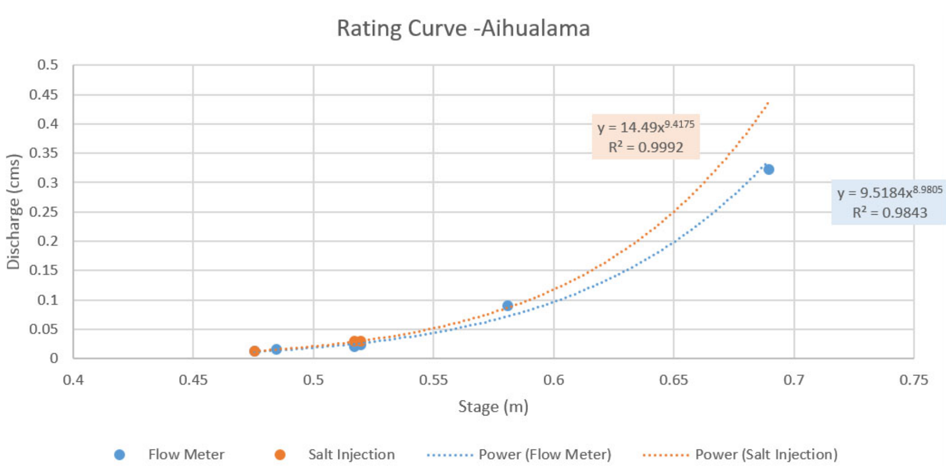

Figure 5. Rating curve of Aihualama Stream used to calibrate the stream monitor. Note: Both rating curves were fitted by power analysis. Blue dots and lines = rating curve established with the velocity cross-section method; orange dots and lines = rating curve established with the salt injection method.

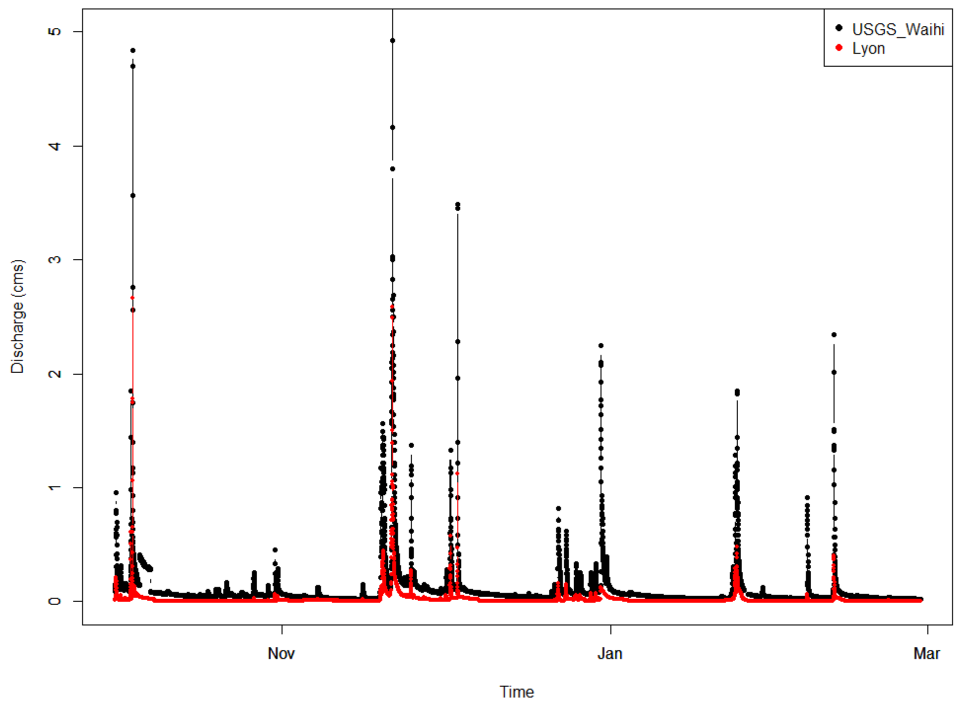

Figure 6. Hydrograph of Waihi and Aihualama stream gauges during the Aihualama stream monitor executive period.

6. Check monitoring records and neighboring stream gauges to confirm and validate the data.

   Our stream gauge measured reasonable stream discharge after comparisons with the USGS Waihi stream gauge (Figure 6).

7. Understanding the typical flow response to precipitation, and describing the main factors that drive the streamflow in a forest watershed.

   We were able to download the rainfall from the NOAA weather station (MNLH MANOA LYON ARBO 785.2, HI US) and plot the data with our discharge data (Figure 7).

8. Getting familiar with the model theory behind Soil and Water Assessment Tool (SWAT).

   Graduate students start reading the literature on SWAT (Arnold et al. 1998, Arnold et al. 2012); also, literature on the application of SWAT to assess crop yields, while minimizing the impact on water resources for the island of Maui (Osorio et al. 2014).

9. Downloading the necessary data to use for SWAT (Figures 8–10):
   - Digital Elevation Model (DEM)—Hawaii Coastal Geology Group (http://www.soest.hawaii.edu/coasts/data/hawaii/dem.html)
   - Soil—Web Soil Survey (WSS) by USDA Natural Resources Conservation Service (NRCS) (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm)
   - Land Cover—NOAA's Coastal Change Analysis Program (C-CAP) (https://coast.noaa.gov/ccapftp/#/)

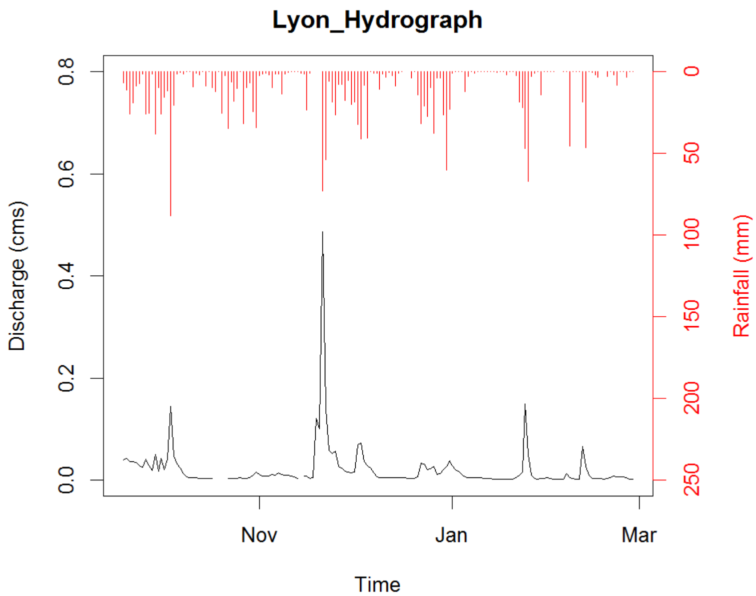

Figure 7. Daily rainfall at Lyon Arboretum (red) and daily discharge at Aihualama Stream (black).

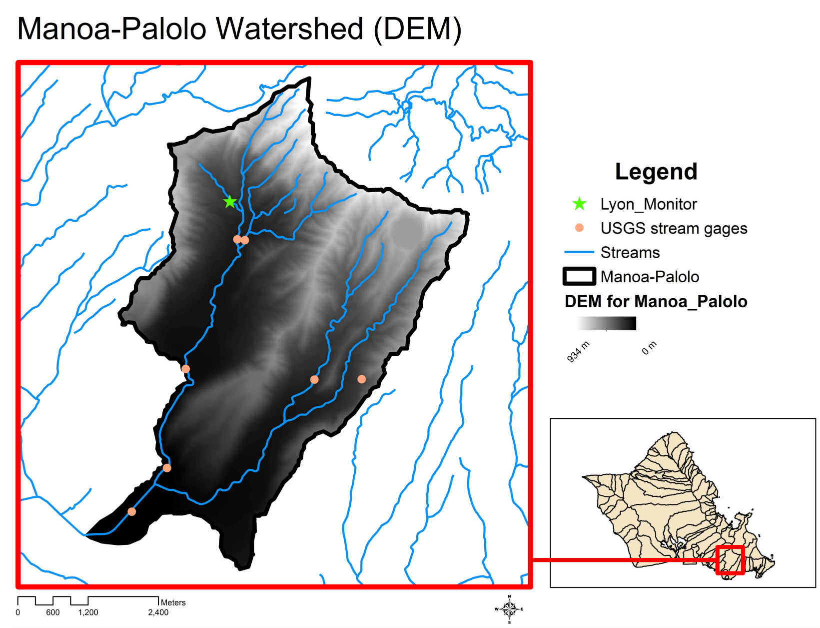

Figure 8. Digital elevation model of Manoa-Palolo Watershed.

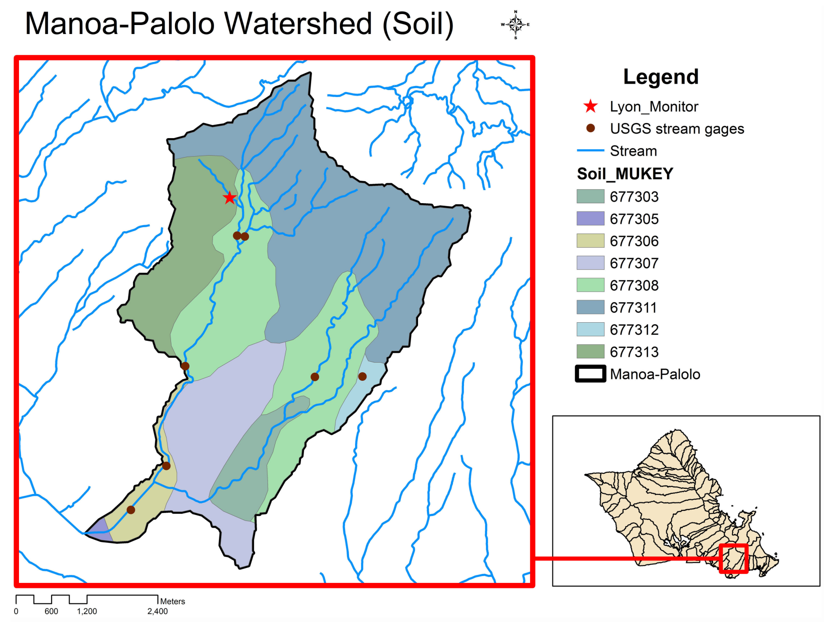

Figure 9. Soil map of Manoa-Palolo Watershed

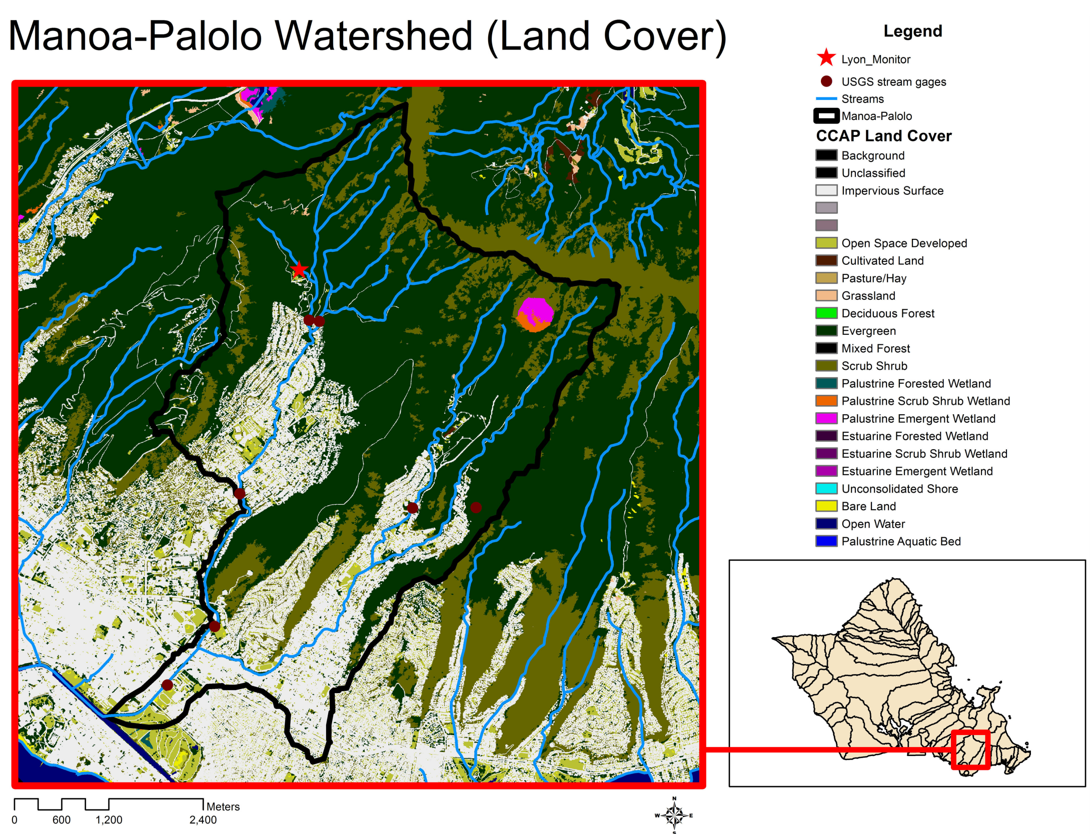

Figure 10. Land cover map of Manoa-Palolo Watershed. Note: There are no Meta information for the two categories below the impervious surface.

Future Work

Objectives to include, pending funding:

- Continue stream monitoring and flow measurement
- Determine a second monitoring location at mid-watershed
- Install second monitoring stream gauge
- Delineate sub-watersheds that best describe the rainfall-runoff response with SWAT model
- Address the characteristic of watershed responses at rainforest watersheds
- Draft, complete, and submit a manuscript
- Present results at an annual conference/meeting

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Huang Y.-F., Tsang, Y.-P., and C. Evensen, "Different approaches of streamflow measurement for rainforest watersheds in Hawaii." (in preparation)

Tsang, Y.-P., A. Strauch, A. Lynch, and D. Infante. 2016. "The natural flow regime of Hawaii streams," Poster presented in 2016 American Geophysical Union, San Francisco, CA, December 12–16, 2016.

Publications Cited in Synopsis

Arnold, J.G., R. Srinivasan, R.S. Muttiah, and J.R. Williams, 1998, "Large area hydrologic modeling and assessment part I: Model development," Journal of the American Water Resources Association, 34(1):73–89, doi: 10.1111/j.1752-1688.1998.tb05961.

Arnold, J.G., D.N. Moriasi, P.W. Gassman, K.C. Abbaspour, M.J. White, R. Srinivasan, C. Santhi, R.D. Harmel, A. van Griensven, M.W. Van Liew, N. Kannan, and M.K. Jha, 2012, "SWAT: model use, calibration, and validation," Transactions of the ASABE, 55(4):1491–1508.

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.-L. Chen, P.-S. Chu, J.K. Eischeid, and D.M. Delparte, 2013, "Online rainfall atlas of Hawaii," Bulletin of the American Meteorological Society, 94:313–316, doi: 10.1175/BAMS-D-11-00228.1.

Moore, R.D.D., 2003, "Introduction to salt dilution gauging for streamflow measurement: Part 1," Streamline Watershed Management Bulletin, 7(4):20–23.

Moore, R.D.D., 2005, "Introduction to salt dilution gauging for streamflow measurement Part III: Slug injection using salt in solution," Streamline Watershed Management Bulletin, 8(2):1–6.

Osorio, J., J. Jeong, K. Bieger, and J. Arnold, 2014, "Influence of potential evapotranspiration on the water balance of sugarcane fields in Maui, Hawaii," Journal of Water Resource and Protection, 6(9):852–868.

Young, K.B., 1950. “A comparative study of mean-section and mid-section methods for computation of discharge measurements,” USGS Open-File Report 53-277, U.S. Geological Survey.

Wastewater treatment for point source processing and resuse

Basic Information

Title:	Wastewater treatment for point source processing and resuse
Project Number:	2016HI460B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Engineering
Focus Category:	Treatment, Wastewater, None
Descriptors:	None
Principal Investigators:	Michael Cooney, Marek Kirs

Publication

1. Teehera, Kim B., S.T. Lin, K.M. Lamichhane, K. Rong, M. Kirs, R. Babcock, M J. Cooney, 2017, "Survivability of Indicator Microorganisms in the High Rate Anaerobic-Aerobic Digester (HRAAD)," Poster presented in 2017 Pacific Water Conference, Honolulu, HI, February 14–16, 2017 (awarded first place).

Problem and Research Objectives

Water limited “island” communities such as those in Hawaii, face mounting demands on their water supply. These demands may include increasing consumption, decreasing rainfall, decreasing groundwater recharge, and the redirection of rainfall over natural watersheds—all of which can stress a pre-existing ground supply of potable water. To protect the existing fresh water supply, there is a viable alternative: using recycled water for activities with less stringent standards (e.g., landscaping and agricultural irrigation). As an added benefit, developing a more cost-effective and low-energy method to reduce fecal pathogen concentrations (from both human and animal sources) in treated water would be extremely advantageous for both the water reuse industry and small- and medium-sized businesses with the potential to use recycled water (R2). Our hypothesis is that biofilms serve as a natural biological matrix that entraps both micropollutants and the pathogenic organisms used in their degradation. Biochar packed biofilm based reactors have the potential to accelerate the entrapment and death of enteric organisms. Biofilms contain a diverse group of microorganisms (Khatoon et al. 2014), that are robust and more resilient to process disturbances (Andreottola et al. 2000), while biochar has been proven to harbor robust biofilms with diverse group of organisms (Cooney et al. 2016).

The objective of this study is to demonstrate the efficacy of low-energy low-chemical biofilm anaerobic-aerobic reactor systems to realize the efficient degradation of enteric pathogens. The project evaluates the survivability of the indicator organisms *Escherichia coli* and F+ specific RNA coliphages through different stages in a biofilm-based high rate anaerobic-aerobic digestion (HRAAD) reactor system. To do so, synthetic wastewater was inoculated with *E. coli* CN-13 and bacteriophages MS2 at concentrations mimicking their concentrations in sewage. These two microbes are recognized as indicator organisms for fecal contamination and recommended by the U.S. Environmental Protection Agency to evaluate the safety of drinking and recreational waters.

Methodology

The HRAAD system was comprised of a biochar packed upflow anaerobic reactor (AnPB), a biochar packed aerobic trickling filter (TF), and a clarifier or settling tank (ST) all connected in the series (Figure 1).

The ST was followed by an overflow filter bay and a final water holding tank (recycle reservoir, RR). The feed (simulated sewage) loaded onto the AnPB reactor flowed over to sequential successive unit operations (i.e., TF, ST, filter bay, and RR) by gravity. The water in the RR was recycled through an external UV light for final polishing (i.e., to remove any residual pathogens in the effluent). The main steps included were:

- Prepared simulated OECD (peptone) sewage.
- Measured background (pre-inoculation) concentrations of indicator organisms (*E. coli* CN-13, surrogate for bacteria, and F+ specific coliphages MS2 [hereafter referred to as bacteriophage MS2], surrogate for viruses) present in the reactor system inclusive of synthetic feed, anaerobic digester column, aerobic trickling filter column, and clarifier column.

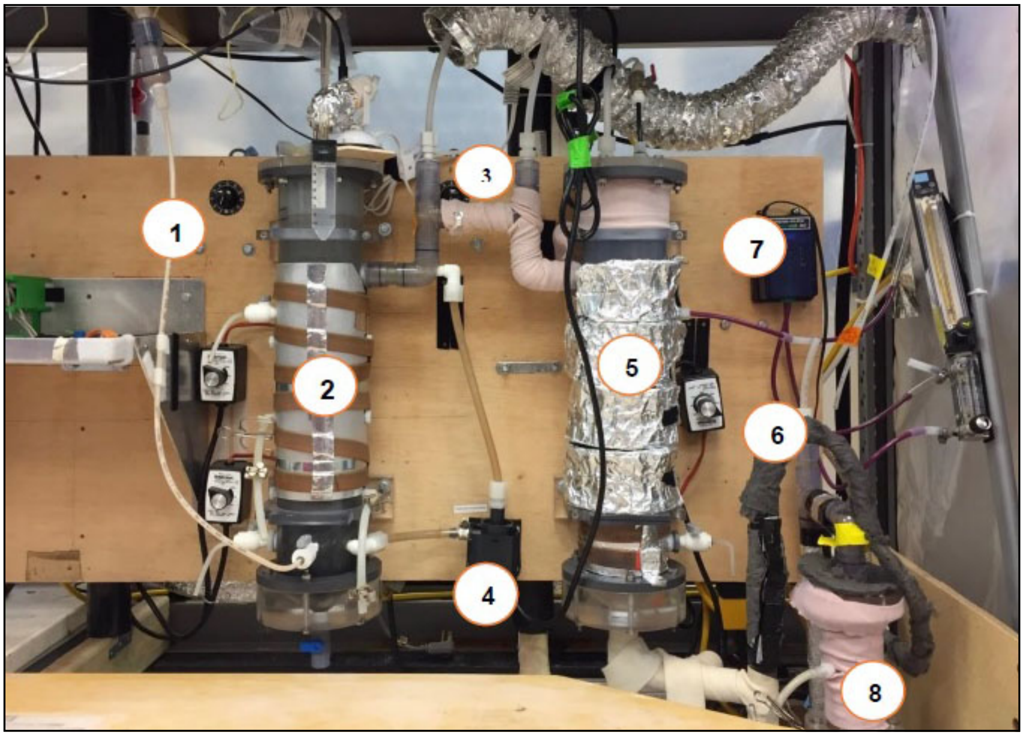

Figure 1. High rate anaerobic aerobic digester system. Legend: 1) feed dosing line, 2) biochar packed up-flow AnPB reactor, 3) flow transfer line, 4) AnPB internal recycle pump, 5) biochar packed TF, 6) TF recycle line, 7) TF air pump, 8) settling tank.

- Prepared seed stocks of *E. coli* CN-13 and bacteriophages MS2, determine organism densities, and evaluate seed stability during storage (seed stocks stored frozen at -80 °C).
- Spiked synthetic feed with seed stocks of indicator organisms in order to maintain a stable and accurate populations of *E. coli* CN-13 and bacteriophages MS2 at concentrations 1×10^8 MPN l^{-1} and 1×10^6 PFU l^{-1}, respectively to mimic the concentrations generally present in raw sewage entering wastewater treatment plants.
- Enumerated (quantified) both indicator organisms (*E. coli* CN-13 and bacteriophages MS2) in liquid phase (effluent) samples collected from different stages of the HRAAD reactor system (anaerobic, aerobic, and clarification) and evaluate the efficiency of the HRAAD system in reducing these indicator organisms in each of the reactor stage and in the system overall.

Principal Findings and Significance

The HRAAD system was loaded with simulated sewage spiked with indicator organisms and the performance monitored for 73 days. In average, one log reduction of *E. coli* and 0.5 log reduction of bacteriophage MS2 was achieved across AnPB. The HRAAD system was able to achieve approximately three log reductions of *E. coli* CN-13 and almost one log reduction of bacteriophage MS2. The system performance in reducing indicator organisms, (i.e., *E. coli*

CN-13 and bacteriophage MS2) over time across HRAAD system components is presented in Figures 2 and 3, respectively.

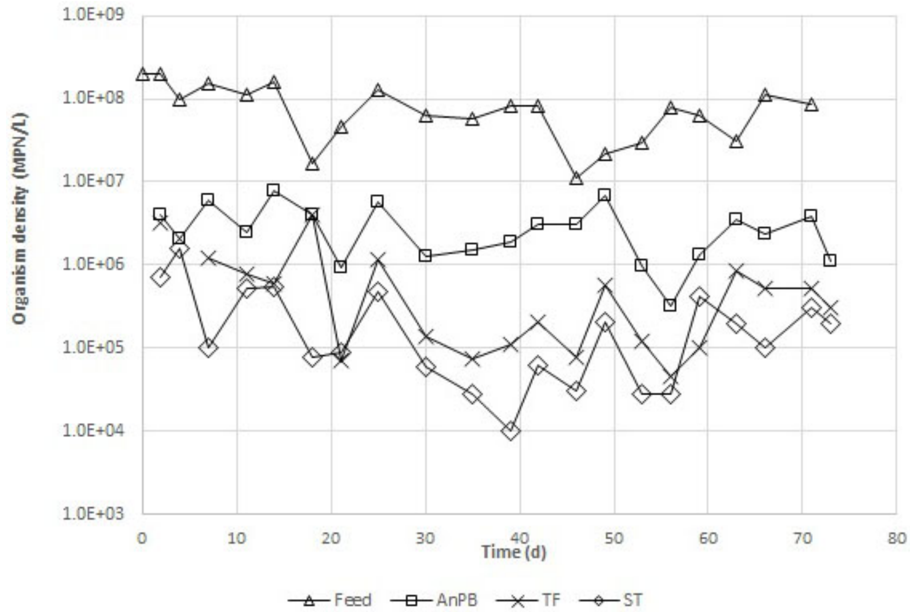

Figure 2. Log reduction of *E. coli* CN-13 over time across HRAAD system components.

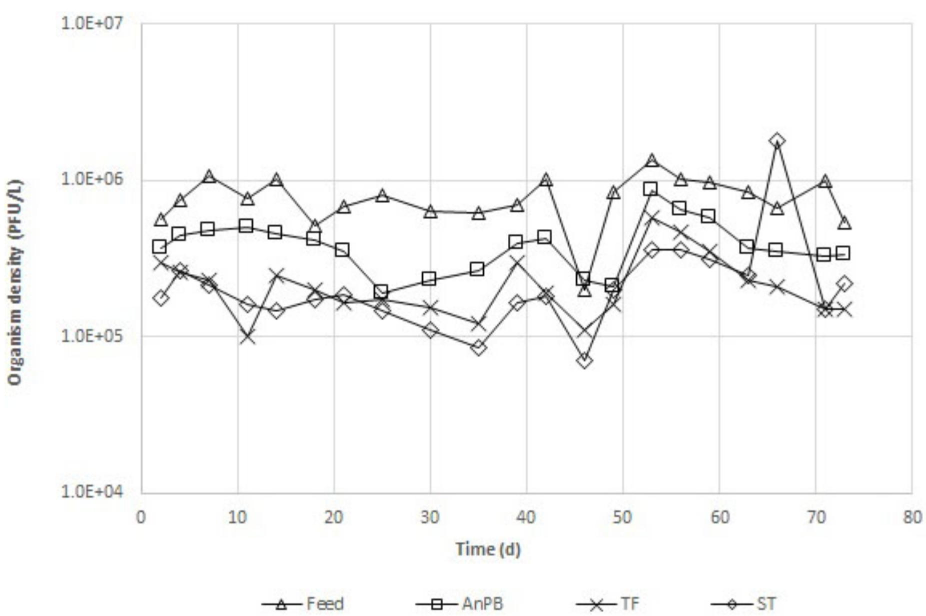

Figure 3. Log reduction of bacteriophage MS2 over time across HRAAD system components.

The background concentrations (before inoculation) of indicator organisms in liquid phase samples were nominal compared to the concentrations of these organisms maintained in the feed. The *E. coli* CN-13 concentrations for the feed tank, AnPB, TF, and, ST were <10 MPN l^{-1}, 5483 MPN l^{-1}, 181 MPN l^{-1}, and 52 MPN l^{-1}, respectively. The bacteriophage MS2 was not detected in the system.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

None

Publications Cited in Synopsis

Andreottola, G., P. Foladori, and M. Ragazzi, 2000, "Upgrading of a small wastewater treatment plant in a cold climate region using a moving bed biofilm reactor (MBBR) system," Water Science and Technology, 14(1):177–185.

Cooney, M.J., K. Lewis, K. Harris, Q. Zhang, and T. Yan, 2016, "Start up performance of biochar packed bed anaerobic digesters," Journal of Water Process Engineering, 9:p. e7–e13.

Khatoon, N., I. Naz, M.I. Ali, N. Ali, A. Jamal, A. Hameed, and S. Ahmed, 2014, "Bacterial succession and degradative changes by biofilm on plastic medium for wastewater treatment," Journal of Basic Microbiology, 54(7):739–749.

Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem

Basic Information

Title:	Influence of anthropogenic and climatic forcing on water quality within a tropical coastal ecosystem
Project Number:	2016HI461B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Methods
Descriptors:	None
Principal Investigators:	Rosanna Alegado

Publications

1. Beebe, Charles, 2018, "Effects of insular mangrove removal on primary productivity within a traditional Hawaiian aquaculture system," M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
2. Moehlenkamp, Paula, 2018, "Influence of mangrove removal on water budget and pathogens in Heeia Fishpond," M.S. Thesis, Department of Oceanography, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, HI. (in preparation)
3. Frank, K.L., K.L. Rogers, C.G. Wheat, and R.A. Alegado, 2016, "Linking benthic microbial community dynamics to diel redox variations in a near shore costal environment, Heeia Fishpond," Poster presented in 2016 American Geophysical Union Fall Conference, San Francisco, CA, December 2016.
4. Nelson, C.E., and R.A. Alegado, "Ridge to reef: Incorporating authentic place-based and community-engaged research experiences into undergraduate environmental science curricula," Poster presented in 2017 American Society for Limnology and Oceanography Meeting, Honolulu, HI, February 2017.

Problem and Research Objectives

Although a number of temperate estuaries have served as systems for studying the influences of climate change on the coastal environment (Cooper and Brush 1993, De Carlo et al. 2007, Officer et al. 1984, Ringuet and Mackenzie 2005), few cognate systems have been thoroughly examined in tropical estuarine environments. Estuaries constitute some of the most geochemically active ecosystems on the planet, and the effects of climate change may be particularly enhanced in these environments due to human activity (Chu 1995, Day et al. 2008, Scavia et al. 2002). Our goal is to link microbial community dynamics and function over physical and chemical gradients in order to identify environmental conditions that are predictive of the microbial community succession following extreme climate events. Such studies may constrain the biogeochemical cycles favored as climate regimes shift.

The objective of this proposal is to analyze the role of stochastic climate events (e.g., storms) on water column microbial community structure by weekly sampling a network of stations within the Heeia Coastal Ocean Observing System (HCOOS) over a 24-month period to describe natural changes in microbial community structure (abundance, diversity, and composition) as a function of seasonable variability and environmental drivers.

Methodology

Deciphering the impact of climate on microbially driven geochemical transformation requires repeat sampling and experimentation across periods of environmental change. To assess the taxonomic biogeography of microorganisms in the Heeia Fishpond (HFP), biological samples were collected concurrently with the biogeochemical and physical oceanography sampling for a co-registered data set. High-resolution sampling allowed the capture of data across a continuum of climatic events, ranging from a neutral baseline to El Niño influenced conditions. Routine samplings were performed every week for 18 months (July 2014–February 2016) at each of the 14 HCOOS stations throughout the HFP. At each station, approximately 1.5 L of bulk seawater was collected from a depth of 30 cm via a Teflon-lined Niskin bottle (General Oceanics Inc., Miami FL) and used for the DNA-based analysis of the microbial community structure, flow cytometric enumeration of planktonic cells, and quantification of macronutrients. Genetic material from size-fractionated microbial communities was extracted from the surface water column as previously performed (Gobet et al. 2012, Yeo et al. 2013). Next generation Illumina "pyrotag" sequencing (Kozich et al. 2013) was used to generate extensive sequencing datasets of 16S and 18S rRNA data to simultaneously characterize diversity in all three domains of life represented in the HFP over the course of the 18 months. Using size-fractionated seawater, the contribution of particles to biological activity will also be evaluated. A multi-parameter water quality monitor sonde (YSI 6600 v2; YSI Incorporated, Yellow Springs, OH) was used to obtain *in situ* profiles of the temperature, salinity, and pH. Nutrients (i.e., nitrate, nitrite, ammonia, phosphate, and silica) were analyzed through the School of Earth Science and Technology (SOEST) Laboratory for Analytical Biogeochemistry (S-LAB). These experiments revealed the contribution of water quality to the particle-attached microbial assemblage, the bulk biological processes, and the response of this community to environmental perturbations. Comparative phylogenetic analysis has the potential to provide significant insight into the environmental drivers of naturally occurring genomic variability and distribution of microbial genes and biochemical mechanisms and higher-order community organization and dynamics within tropical coastal ecosystems.

Principle Findings and Significance

In the first year of the grant, archived samples were DNA extracted and processed for Illumina 16S sequencing. Sequencing was completed and we are in the process of analyzing the data to determine which biogeochemical and physical parameters co-vary with microbial community dynamics.

Starting in January 2017, we augmented our sampling regime to determine how restoration has altered the fishpond water budget. Initially characterized in 2008, the subsequent removal of the mangroves and restoration of the fishpond wall and sluice gates have likely changed the flow regime and circulation. Notably, the repair of the 100-yard "ocean break" was completed in December 2015. The break had fundamentally altered the functioning of the fishpond since it occurred in 1965 during the Keapuka Flood. We deployed current meters into each of the sluice gates to measure water exchange over several tidal cycles including the newly built Kahookele sluice gate. From these data, we will be able to calculate volume and nutrient flux over tidal cycles.

Finally, we applied multivariate analysis to characterize the structure of the water column in the fishpond (Figure 1). We identified two zones dominated primarily by low salinity, low dissolved O_2, and cooler water on the landward side of the mangrove island. The ocean and first river makaha can be binned into two zones with oceanic characteristics. Of these two oceanic zones, the more southwestern makaha has much higher dissolved oxygen (DO), temperature, and pH. Finally, a mid-pond zone characterized by median temperature, salinity, and pH values was observed. We hypothesize that microbial communities will partition along these zones.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Project/Proposal Title: Heeia Fishpond Mangrove Removal and Water Quality Improvement
PI: Maya Walton (UHM SOEST/Sea Grant), Co-PI: R. Alegado (UHM SOEST/OCN)
Source of Support: Hawaii State Department of Health, Clean Water Branch
Amount of Award: $26,940.33 (of $189,504.70) to R. Alegado
Project Period: 03/01/2017–02/28/2019
Location of the Project: Hawaii

Project/Proposal Title: Increasing Food Security in the Hawaiian Islands by Increasing Capacity for Traditional Coastal Aquaculture
PI: Darren Lerner (UHM SOEST/Sea Grant), Co-PI: R. Alegado (UHM SOEST/OCN)
Source of Support: NOAA National Sea Grant Office Aquaculture Initiative
Amount of Award: $165,580.00 (of $656,004.14) to R. Alegado
Project Period: 09/01/2017–8/31/2020
Location of the Project: Hawaii

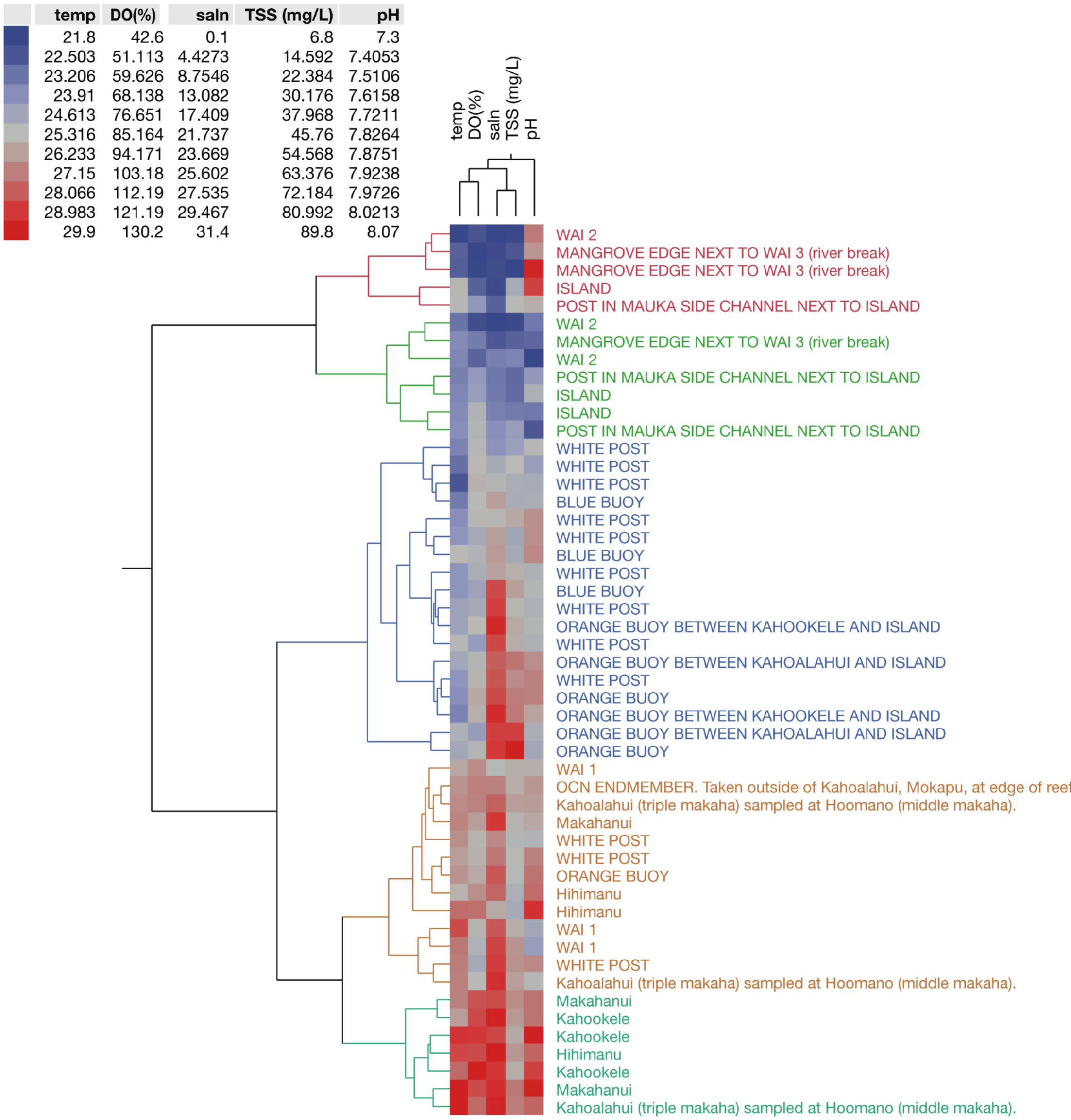

Figure 1. Multivariate analysis of water quality parameters (temperature = temp, dissolved oxygen = DO, salinity = saln, total suspended solids = TSS, and pH) reveals distinct zones within Heeia Fishpond. Red and green sites are dominated by low salinity and is on the landward side of the mangrove island; blue sites are in the mid-pond zone; brown and mint sites are dominated by high salinity and warmer temperature water.

Publications Cited in Synopsis

Chu, P.-S., 1995, “Hawaii Rainfall Anomalies and El Niño,” Journal of Climate, 8(6):1697–1703. http://doi.org/10.1175/1520-0442(1995)008<1697:HRAAEN>2.0.CO;2

Cooper, S.R., and G.S. Brush, 1993, “A 2,500-year history of anoxia and eutrophication in Chesapeake Bay,” Estuaries, 16(3):617–626.

Day, J.W., R.R. Christian, D.M. Boesch, A. Yáñez-Arancibia, J. Morris, R.R. Twilley, L. Naylor, L. Schaffner, and C. Stevenson. 2008. “Consequences of climate change on the ecogeomorphology of coastal wetlands,” Estuaries and Coasts, 31(3):477–491.

De Carlo, E.H., D.J. Hoover, C.W. Young, R.S. Hoover, and F.T. Mackenzie, 2007, “Impact of storm runoff from tropical watersheds on coastal water quality and productivity,” Applied Geochemistry, 22(8):1777–1797. http://doi.org/10.1016/j.apgeochem.2007.03.034

Gobet, A., S.I. Böer, S.M. Huse, J.E.E. van Beusekom, C. Quince, M.L. Sogin, A. Boetius, and A. Ramette, 2012, “Diversity and dynamics of rare and of resident bacterial populations in coastal sands,” The ISME Journal, 6(3): 542–553. http://doi.org/10.1038/ismej.2011.132

Kozich, J.J., S.L. Westcott, N.T. Baxter, S.K. Highlander, and P.D. Schloss, 2013, “Development of a dual-index sequencing strategy and curation pipeline for analyzing amplicon sequence data on the MiSeq Illumina sequencing platform,” Applied and Environmental Microbiology, 79(17):5112–5120. http://doi.org/10.1128/AEM.01043-13

Officer, C.B., R.B. Biggs, J.L. Taft, L.E. Cronin, M.A. Tyler, and W.R. Boynton, 1984, “Chesapeake bay anoxia: origin, development, and significance,” Science (New York, NY), 223(4631):22–27. http://doi.org/10.1126/science.223.4631.22

Ringuet, S., and F.T. Mackenzie, 2005, “Controls on nutrient and phytoplankton dynamics during normal flow and storm runoff conditions, southern Kaneohe Bay, Hawaii,” Estuaries, 28(3):327–337.

Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, and J.G. Titus, 2002, “Climate change impacts on US coastal and marine ecosystems,” Estuaries, 25(2):149–164.

Yeo, S.K., M.J. Huggett, A. Eiler, and M.S. Rappé, 2013, “Coastal bacterioplankton community dynamics in response to a natural disturbance,” PLoS One, 8(2):e56207. http://doi.org/10.1371/journal.pone.0056207

IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU

Basic Information

Title:	IDENTIFYING GROUNDWATER FLOW AND CONTAMINATION TO STREAMS: KAHALUU WATERSHED, OAHU
Project Number:	2016HI462B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Wastewater, Hydrology
Descriptors:	None
Principal Investigators:	Craig R Glenn, Henrieta Dulai

Publications

1. Dores, D., M. Mathioudakis, C. Glenn, R. Whittier, and H. Dulai, 2017, "Identifying pollutant sources along groundwater flowpaths in Kaneohe, Oahu, Hawaii," in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.
2. Mathioudakis, M., C. Glenn, and D. Dores, 2017, "Examining groundwater and surface water interactions to determine the effects of anthropogenic nutrient loading on stream and coastal water quality," in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.

Problem and Research Objectives

The risk that sewage effluent released to the environment poses to human health and the environment is well documented. On-site sewage disposal systems (OSDS) are a substantial threat to groundwater quality and the second most frequently reported cause of contaminated groundwater in the United States (USEPA 2007), as high system density or improper function can lead to contamination of aquifers and adjacent surface waters by nutrients, pathogens and pharmaceuticals (Beal et al. 2005, Swartz 2006). Located in adjacent watersheds that supply groundwaters to Kaneohe Bay are over 1,600 cesspools or other OSDS. While some introduction of sewage contamination may be due to overland flow during storm events causing OSDS to overflow, there is also chronic introduction of sewage contamination by the discharge of groundwater to streams. To identify the areas and more importantly the OSDS that are the primary source of wastewater contamination to the streams and the ocean, stream reaches where groundwater discharges to the stream need to be identified.

Methodology

Our team has conducted remote-controlled drone flights mapping groundwater discharge to streams and to the coastal waters of Kaneohe and is pioneering the use and data processing of high-resolution thermal imagery obtained to locate, quantify, and monitor submarine groundwater discharge (SGD) to coastal waters. We have used a fully autonomous 3DR X-8+ Octocopter UAV (unmanned aerial vehicle) equipped with a high resolution (<0.1C) FLIR TAU 2 640 radiometrically calibrated FLIR camera with integrated TEAX digital storage system. The temperature of groundwater in the region is relatively constant through time (~20°C +/- 0.3°C), whereas surface water temperatures vary on seasonal and diurnal cycles (e.g., ~20° to 24°C at Kahaluu Stream, averaging 22°C in November 2014). This thermal signature allows groundwater discharge to be located at the surface and along streambanks with thermal imaging.

Initial seepage runs were completed on Kahaluu and Waihee Streams during baseflow conditions to determine stream loss or gain from groundwater. Measurement sites were spaced every 0.5 km between USGS gaging stations and the shoreline. Flow and depth measurements were taken with a SonTek FlowTracker® acoustic velocity meter. A stream gaging station has been set in each stream to continuously measure the influx of groundwater. Each station consists of a series of simultaneous stream stage and stream flow measurements to develop a stream-rating curve. A pressure logger is installed in a stilling well to continuously measure stream stage. The stream's loss or gain from groundwater will be estimated based on the difference between the flow measured at adjacent gaging stations.

Ratios of stable isotopes hydrogen (δD) and oxygen ($\delta^{18}O$) in water have been used across the world to determine groundwater flow paths, particularly with the creation of local meteoric water lines (LMWL). To use δD and $\delta^{18}O$ as source water tracers for ground and surface water systems, values must be established in local precipitation for Oahu. As groundwater is recharged by precipitation infiltration, rainfall locations can be identified as recharge zones corresponding to particular aquifers, and thus to the streams those aquifers feed as base flow. Samples from precipitation collectors will be compared to samples from groundwater wells and surface water streams. A network of 16 precipitation collectors have been deployed across the island to collect rainfall on both the windward and leeward sides.

Principal Findings and Significance

As a LMWL for the Kaneohe region will take months to attain verifiable accuracy, a groundwater model for windward Oahu has been created to establish the most probable groundwater flow vectors using ESRI ArcGIS and the MODFLOW and MT3DMS packages in Aquaveo Groundwater Modeling System. Along the stations for the seepage runs and previous Hawaii Department of Health pathogen studies, nutrients samples were taken for nitrate concentration, phosphate concentration, and the isotopic composition of nitrate. High nitrate concentrations were found in areas of high OSDS. Further, high $\delta^{15}N$ values in the surface waters of certain regions throughout Kahaluu watershed are consistent with values characteristic of the nitrate composition of wastewater found in previous research. There is a correlation between an area of high OSDS density and high $\delta^{15}N$ of nitrate, but further samples of the stream and surrounding region remain required.

OSDS effluent can degrade the environment by increasing the biologic productivity in streams and near shore waters (Giblin and Gaines 1990). Nitrate and phosphate, both enriched in OSDS effluent, are the most common limiting nutrients. Excessive concentrations of either or both of these can result in over production of plant matter crowding out native plants, producing hypoxic conditions in the lower water column, and causing toxic algal blooms (Lapointe et al. 1990). Developing a complete understanding of the environmental and health risks of wastewater leakage from OSDS thus remains a fundamental and critical concern for the State of Hawaii. Regarding human-health risks, surface waters in the Kahaluu Lagoon (on the windward side of Oahu) fronted by Kaneohe Bay have shown to have very high levels of wastewater related bacteria (e.g., Star Advertiser, November 01, 2014), now labeled by Hawaii media and lawmakers as the “poster child of the Hawaii cesspool issue” (KHNL News Now 2015).

Publications/Presentations and Proposals or Projects Initiated Based on this Research

Dores, D., M. Mathioudakis, C. Glenn, R. Whittier, and H. Dulai, 2017, “Identifying pollutant sources along groundwater flowpaths in Kaneohe, Oahu, Hawaii,” in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.

Mathioudakis, M., C. Glenn, and D. Dores, 2017, “Examining groundwater and surface water interactions to determine the effects of anthropogenic nutrient loading on stream and coastal water quality,” in 2017 Geological Society of America Cordilleran Section 113th Meeting, May 23–25, 2017, Honolulu, Hawaii.

Publications Cited in Synopsis

Beal, C.D., E.A. Gardner, and N.W. Menzies, 2005, "Process, performance, and pollution potential: A review of septic tank–soil absorption systems," Australian Journal of Soil Research, 43(7):781–802.

Giblin, A.E., and A.G. Gaines, 1990, "Nitrogen inputs to a marine embayment: The importance of groundwater," Biogeochemistry, 10(3):309–328.

KHNL News Now, November 5, 2015. http://www.Hawaiinewsnow.com/story/30445605/warning-signs-remain-posted-at-Kahaluulagoon-due-to-continued-high-bacteria-levels (access date May 18, 2017).

Lapointe, B.E., J.D. O'Connell, and G.S. Garrett, 1990, "Nutrient couplings between on-site sewage disposal systems, groundwaters, and nearshore surface waters of the Florida Keys," Biogeochemistry, 10(3):289–307.

Swartz, C.H., S. Reddy, M.J. Benotti, H. Yin, L.B. Barber, B.J. Brownawell, and R.A. Rudel, 2006, "Steroid estrogens, nonylphenol ethoxylate metabolites, and other wastewater contaminants in groundwater affected by a residential septic system on Cape Cod, MA," Environmental Science & Technology, 40(16):4894–4902.

USEPA, 2007, "Residential nutrient reduction," U.S. Environmental Protection Agency 2.

Microbial communities and sources of bacteria in Honolulu’s water supply

Basic Information

Title:	Microbial communities and sources of bacteria in Honolulu’s water supply
Project Number:	2016HI463B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	Hawaii
Research Category:	Water Quality
Focus Category:	Groundwater, Water Quality, Water Supply
Descriptors:	None
Principal Investigators:	Marek Kirs

Publication

1. There are no publications for 2016.

Problem and Research Objectives

Issue I. No information on microbes living in Hawaii aquifers. A literature search on "microbial communities," "groundwater," and "Hawaii" reveals no relevant related peer-reviewed articles. Without previous data on ambient microbial communities in Hawaii's groundwater we are unable to identify impacts to, nor recovery of, the compromised aquifers based on microbiological data. Climate change is projected to increase risk to people, assets, economies, and ecosystems (IPCC 2014). Extreme weather events, such as tropical storms and hurricanes, are projected to increase in frequency and intensity in the Pacific. It is well established that shifts in rainfall driven by climate change are anticipated to affect watershed processes (Coffey et al. 2014, Strauch et al. 2014), which will probably affect the supply and quality of groundwater. Recent modeling efforts indicate that shifts in rainfall and increased urbanization alter inputs of fecal indicator bacteria in tropical watersheds (Strauch et al. 2014) as well as distribution of environmental pathogens (Coffey et al. 2014, Urquhart et al. 2014), however the impact is not well understood.

Issue II. Hawaii's drinking water supply is also vulnerable to biological and chemical sabotage (Fujioka et al. 2006). This vulnerability is a definite concern as the current political climate is probably the most volatile since the cold war. Terrorist attacks targeting our water supply could affect its microbiology. Currently, we don't know what microbes live in our groundwater as the technologies available to study microbial communities have been inadequate. Therefore, there is a lack of information on what a typical microbiological background in our drinking water supply consists of, ergo we are not able to detect changes when an aquifer has been compromised.

Issue III. Contamination of groundwater with direct surface water input. This situation is another critical issue for some Pacific Islands (Hawaii, American Samoa, and others). Total coliforms and *Escherichia coli*, routinely assayed for in drinking water quality monitoring programs world-wide, are not reliable indicators of fecal contamination as both groups are widespread in tropical soils where they grow at ambient temperatures (Hardina and Fujioka 1991, Byappanahalli et al. 2012). Hence, when these indicator bacteria are detected in source water, it must be determined whether they are truly of fecal origin or if they were leached from soils and sediments with rainfall. If the source of indicator bacteria is soil, it is expected to be of no or low risk to human health, while contamination with human sewage is of greater concern. Most importantly, effective remediation strategies can be applied to mitigate the impact to the water supply when the source of contaminants is identified.

The overarching goal of this project is to characterize microbial communities and sources of microbes in Honolulu's water supply. Consequently the nature of the project is the microbiological analyses of our water supply. This is the first in-depth analysis (checklist) of microbes in our water supply that combines cultivation based and molecular approaches. The two main objectives are (1) identify the microbial community structure in our drinking water system (source water and distribution system); and (2) determine the source of the indicator bacteria (e.g., sewage, soil, or biofilm), if found, in well and tunnel water samples.

Methodology

During the first year of the project (03/01/16–02/28/17), 36 source water samples and 36 soil samples were collected. Source water samples were collected from 27 wells and nine tunnel water ports owned and selected by the Honolulu Board of Water Supply (BWS). The sample locations were selected to represent a variety of Oahu aquifers used by the BWS as drinking water sources. However, the actual wells and tunnel water outlets selected by the BWS were based on the monitoring data, which found the indicator organisms present.

Sampling was conducted in conjunction with the routine sampling program schedule established by the BWS, and no BWS resources were utilized to complete this study. For those reasons, time at each collection site was very limited, and it was not possible to collect samples using in-situ ultrafiltration, which involves a one-hour filtration process at each site and additional setup/take down time.

Samples were collected from 15 July 2016 to 29 December 2016. Collection of the distribution water samples at the point of use is ongoing. Typically, we were granted access to one to three wells or tunnels on each collection date. Eight liters of source water were collected for microbial community analyses. An additional one liter of source water samples were collected at each location for the analysis of cultivable microorganism (i.e., total coliforms, *E. coli, Clostridium perfringens*, and F+ specific coliphages) and molecular sewage-specific markers (i.e., human-associated *Bacteroides* and human polyomaviruses). Water samples were collected at each site from a flamed sampling port and transported on ice to the Water Resources Research Center laboratory. The laboratory samples were filtered onto sterile hydrophilic polyethersulfone membrane filters (Supor®200, 0.2 µm pore size; Pall Corp., Ann Arbor, MI) and stored at -80°C. After completion of the sample collection, the bacterial DNA was extracted from the filters using the PowerSoil® DNA Isolation Kit (MO BIO Laboratories, Inc.; Carlsbad, CA) according to the manufacturer's protocol, with two minutes of bead beating at maximum speed on a Mini Beadbeater™ (Biospec Products Inc;. Bartlesville, OK). All DNA samples were recovered into a 100 µl elution buffer and stored at -80°C. Total coliform, *E. coli*, *C. perfringens*, F+ specific coliphages, and the molecular sewage-specific marker concentrations were determined as described earlier (Kirs et al. 2017). Microbial community structure will be determined in those samples and distribution system water samples simultaneously once the collection of distribution system water samples is complete.

Principal Findings and Significance

Source Water Samples

Six of the 36 samples (17%) were positive for total coliforms, indicating that some of the sources are affected by microbial contaminants. Nevertheless, no *E. coli* or *C. perfringens* were detected in any of the water samples analyzed. No sewage-specific markers (human-associated *Bacteroides*, human polyomavirues), or coliphages were detected in any of the source water samples.

Soil Samples

All soil samples were positive for total coliforms and enterococci. Geometric mean concentrations of both organisms were 450 MPN/g and 22 MPN/g, respectively, but frequently exceeded >2,419.6 MPN/g of soil (64% and 8% samples, respectively). *E. coli* was detected in 55% of the samples, and the concentrations varied from <1 to >2,419.6 MPN/g (geometric mean = 13 MPN/g). *C. perfringens* was detected in 39% of the soil samples (geometric mean = 50 CFU/g) and the concentrations ranged from <1 to 620 CFU/g.

We hope that the analyses of microbial communities will enable us to determine the source of total coliforms in the well and tunnel water samples that were positive for this group of bacteria. Currently there are two possibilities, (1) coliform bacteria resident to biofilms are compromising water samples, or (2) bacteria from the soil may be leaching into the well and tunnel water system. These coliform bacteria do not appear to be from sewage as no sewage specific markers were detected in the source water samples. The analysis of the soil samples for the microbial source-tracking markers is ongoing. The microbial community analyses will provide further evidence on the source of bacterial contaminants and the associated risks, and will be completed once the samples from the distribution system are collected.

Publications/Presentations and Proposals or Projects Initiated Based on this Research

None

Publications Cited in Synopsis

Byappanahalli, M.N., B.M. Roll, and R.S. Fujioka, 2012, "Evidence for occurrence, persistence, and growth potential of *Escherichia coli* and enterococci in Hawaii's soil environments," Microbes and the Environment, 27(2):164–170.

Coffey, R., B. Bemham, L.A. Krometis, M.L. Wolfe, and E. Cummins, 2014, "Assessing the effects of climate change on waterborne microorganisms: Implications for EU and US water policy," Human and Ecological Risk Assessment, 20(3):724–742.

Fujioka, R.S., A.Y. Asahina, D.M. Sato, and B.A. Yoneyama, 2006, "Development and implementation of a water monitoring plan to prepare for criminal and terroristic contamination of a drinking water system," Unedited Report WRRC-2006-02, Water Resources Research Center, University of Hawaii at Manoa, Honolulu.

Hardina, C.M, and R.S. Fujioka, 1991, "Soil: The environmental source of *Escherichia coli* and enterococci in Hawaii's streams," Environmental Toxicology and Water Quality, 6:185–195.

Intergovernmental Panel on Climate Change (IPCC), 2014, "Climate Change 2014: Synthesis Report," Approved Summary for Policy Makers, pp. 1–40. IPCC Fifth Assessment Synthesis Report, November 1, 2014, SPM-1.

Kirs, M., V. Kisand, M. Wong, R.A. Caffaro-Filho, P. Moravcik, V.J. Harwood, B. Yoneyama, and R.S. Fujioka, 2017, "Multiple lines of evidence to identify sewage as the cause of water quality impairment in an urbanized tropical watershed," Water Research, 116:23–33.

Strauch, A.M., R.A. Mackenzie, G.L. Bruland, R. Tingley, and C.P. Giardina, 2014, "Climate change and land use drivers of fecal bacteria in tropical hawaiian rivers," Journal of Environmental Quality, 43(4):1475–1483.

Urquhart, E.A., B.F. Zaitchik, D.W. Waugh, S.D. Guikema, and C.E. Del Castillo, 2014, "Uncertainty in model predictions of Vibrio vulnificus response to climate variability and change: A Chesapeake Bay case study," PloS One 9: e98256.

Information Transfer Program Introduction

None.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016AS458B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	1st
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	None
Principal Investigators:	Philip Moravcik

Publications

1. Kirs, M., V. Kisand, M. Wong, R.A. Caffaro-Filho, P. Moravcik, V.J. Harwood, B. Yoneyama, and R.S. Fujioka, 2017, “Multiple lines of evidence to identify sewage as the cause of water quality impairment in an urbanized tropical watershed,” Water Research, 116:23–33.
2. Kirs, M., P. Moravcik, P. Gyawali, K. Hamilton, V. Kisand, I. Gurr, C. Shuler, and W. Ahmed, 2017, “Rainwater harvesting in American Samoa: Current practices and indicative health risks,” Environmental Science and Pollution Research, pp. 1–9, doi:10.1007/s11356-017-8858-z.

Introduction

During FY2016, WRRC continued to further the goal of broadening knowledge and appreciation of American Samoa's water resources. Building upon the January 2016 workshop held in Pago Pago, WRRC was instrumental in establishing an advisory committee for American Samoa. The council was created to help guide and to direct WRRC in the need for and direction of future research in American Samoa. Committee members were recruited from the American Samoa Power Authority (the utility in charge of the piped water system), the American Samoa Department of Agriculture, the American Samoan office of the National Oceanic and Atmospheric Administration, American Samoa Community College, the American Samoa office of the Environmental Protection Agency, and the University of Hawaii Sea Grant extension agent resident in American Samoa.

Problem and Research Objectives

The "problems" that this project sought to mitigate are several; there is a lack of scientific and policy knowledge concerning water issues among American Samoa's general populace. American Samoa has a number of pressing water challenges including: (1) provision of adequate clean, fresh water to a population that is spread throughout Tutuila, (2) proper collection, (3) treatment and disposal of wastewater from these same spread out communities, (4) protection of surface water resources in the face of intensive land use, and (5) protection of nearshore marine resources from contamination borne by discharges from the land.

Technology Transfer Office Activities

The principal activity of the Technical Transfer Office (TTO) during this period was to establish the American Samoa Advisory Committee. Members would assist in identifying priority issues that need research on the island. Following up on a recent field study for rainwater harvesting practices conducted in January 2017, the TTO distributed guidelines to catchment's users to assist them in improving the quality of the rainwater they were collecting. In conjunction with the Hawaii water center, information about the current research held in American Samoa are featured at the Hawaii WRRC website (www.wrrc.hawaii.edu).

Newly Appointed American Samoa Advisory Council Members

- Kelley L. Anderson Tagarino, Extension Faculty, American Samoa Community College/ University of Hawaii Sea Grant
- Utu Abe Malae, Executive Director, American Samoa Power Authority
- Peter Gurr, Deputy Director, American Samoa Department of Agriculture
- Hideyo Hattori, American Samoa Management Liaison, Coral Reef Conservation Program and Coastal Zone Management Program, National Oceanic and Atmospheric Administration Program
- Mark Schmaedick, Entomologist, American Samoa Community College
- Tim Bodell, American Samoa Environmental Protection Agency

Editing

The TTO was involved in the fieldwork and the report writing for research done on rainwater catchments use on Tutuila and Aunuu islands. This work was recently published in the Environmental Science and Pollution Research journal (Rainwater harvesting in American Samoa: Current practices and indicative health risks by Kirs, M., P. Moravcik, P. Gyawali, K. Hamilton, V. Kisand, I. Gurr, C. Shuler, and W. Ahmed, 2017. doi:10.1007/s11356-017-8858-z).

WRRIP 104B Grants

The TTO reviewed and selected proposals pertaining to water issues in American Samoa made under the WRRIP 104B program.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016HI464B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	1st
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	None
Principal Investigators:	Philip Moravcik

Publications

1. Kirs, M., V. Kisand, M. Wong, R.A. Caffaro-Filho, P. Moravcik, V.J. Harwood, B. Yoneyama, and R.S. Fujioka, 2017, “Multiple lines of evidence to identify sewage as the cause of water quality impairment in an urbanized tropical watershed,” Water Research, 116:23–33.
2. Kirs, M., P. Moravcik, P. Gyawali, K. Hamilton, V. Kisand, I. Gurr, C. Shuler, and W. Ahmed, 2017, “Rainwater harvesting in American Samoa: Current practices and indicative health risks,” Environmental Science and Pollution Research, pp. 1–9, doi:10.1007/s11356-017-8858-z.

Introduction

During FY2016, WRRC continued to further the goal of broadening knowledge and appreciation of Hawaii's water resources. WRRC's Technology Transfer Office (TTO) organized seminars, workshops, and conferences, produced posters and other materials for presentations, and maintained the Center's website. The Technology Transfer Specialist was active in meeting with agency personnel, assisting with proposal writing, research project implementation, and contributing to report authorship for the Center's research projects.

Problem and Research Objectives

The "problems" that this project sought to mitigate are several; there is a lack of scientific and policy knowledge concerning water issues among Hawaii's general populace; there is considerable misinformation about water circulating in the public domain; there is a lack of understanding and appreciation of the value of water research conducted at the University among policy makers and governmental agencies in the state. Under this project WRRC sought to redress these problems through our outreach/educational activities. Our objective was to inform the public and governmental agencies to improve the understanding and management of water resources in Hawaii and the region.

Technology Transfer Office Activities

The TTO employed a range of media to disseminate the Center's research through their bulletins and publications; web site; workshops, meetings, and conferences; and regular seminars. All served to aid the Center in transferring information concerning water resource research and issues.

WRRC's TTO activities included:

- Organizing WRRC Spring and Fall seminars
- Participating in research projects, meetings, conferences, school science fairs
- Providing research information and assistance to consultants, students of all levels, and the general public
- Updating the Center's web site with current research activities and information

WRRC Seminars

The TTO organized biweekly seminar series designed to foster communication among WRRC researchers, students, and the organizational target audience of government agencies, private-sector researchers, and members of the general public with an interest in water resource issues. The following is a list of the seminars presented in FY2016.

Spring 2016 Seminar

Mar. 2, 2016	*Influence of Anthropogenic and Climatic Forcing on Water Quality Within a Tropical Coastal Ecosystem*	Rosie Alegado, Assistant Professor, Department of Oceanography and Center for Microbial Oceanography: Research and Education, University of Hawaii at Manoa
Mar. 2, 2016	*Validating Vegetation Index Time Series Data from Suomi NPP Visible Infrared Imaging Radiometer Suite*	Tomoaki Miura, Associate Professor, Natural Resources and Environmental Management, University of Hawaii at Manoa
Mar. 11, 2016	*Watershed Hydrological Modeling and Climate Change Impact Assessment in Oahu Island*	Olkeba T. Leta, Postdoctoral Fellow, Water Resources Research Center, University of Hawaii at Manoa
Mar. 15, 2016	*Source Partitioning of Anthropogenic Groundwater Nitrogen, Tutuila, American Samoa*	Christopher Shuler, Department of Geology and Geophysics, University of Hawaii at Manoa
Apr. 20, 2016	*Of Microbes and Mucus: Coral Reef Organic Geochemistry in the Anthropocene*	Craig Nelson, Center for Microbial Oceanography: Research and Education, University of Hawaii at Manoa
Apr. 21, 2016	*Hydroecology of River Corridors from Bedforms to Basins*	Judson Harvey, USGS, Reston, VA
May 5, 2016	*Global Contaminants of Emerging Concern and Wastewater Reuse Leaching Risks for Oahu, Hawaii*	Jeffrey Murl, Department of Geology and Geophysics, University of Hawaii at Manoa

Fall 2016 Seminar

Aug. 24, 2016	*Alternative Data-Fusion Strategies for Solutions in Hydrogeology*	Michael Friedel, GNS Science, Hydrogeology, Lower Hutt, NZ and University Colorado, Mathematical & Statistical Sciences, Denver, CO
Aug. 25, 2016	*Toward an Integrated Understanding of the Role of Natural Nanoparticles in Biogeochemistry and Hydrology*	
Sept. 20, 2016	*The Challenges of Providing Landslide Information During an Emergency Response*	Jerome De Graff, 2015–2016 Richard H. Jahns, Distinguished Lecturer in Applied Geology
Sept. 21, 2016	*The ‘Ike Wai Project: Securing Hawaii’s Water Future*	Gwen Jacobs, Director of Cyberinfrastructure, University of Hawaii System

Fall 2016 Seminar—*Continued*.

Oct. 18, 2016	*Organic Micropollutants in Wastewater (Definitions, Production and Consumption of Pharmaceuticals, Sources and Pathways in the Environment, Environmental Effects) and the Main Biological Assays that can be Applied for Wastewater Monitoring.*	Matteo Papa, Postdoctoral Fulbright Scholar at WEX | Water Energy Nexus Research Center, Department of Civil and Environmental Engineering, University of California, Irvine
Nov. 16, 2016	*Marine Worm Communities at Oahu's Sand Island Ocean Outfall: Abundance, Diversity and New Species*	Wagner Magalhaes, Postdoctoral Researcher, Zoology Department, University of Hawaii at Manoa

WRRC Website

The Center's website (www.wrrc.hawaii.edu) is continuously updated with information about WRRC's research activities, seminars, reports, meetings, grant announcements, and the Center's L. Stephen Lau scholarship fund. The site provides information about the Center's facilities and personnel as well as a database for WRRC's publications. A web-site search function provides easy access to the available information.

Digitization and Online Posting of Center Publications

The Center continues to provide their published material as they become available to the University of Hawaii at Manoa's ScholarSpace institutional repository database. These reports are available for download in a PDF format at http://scholarspace.manoa.hawaii.edu/.

Poster Production

Poster design and production services were provided to the Center's faculty and graduate research assistants for presentations at meetings and conferences.

Editing

Editorial services for numerous reports and articles were provided during the reporting period. This work helps to disseminate the Center's research results through journals and other publications.

L. Stephen Lau Scholarship

Application review, and applicant selection for the Center's L. Stephen Lau Scholarship is coordinated through TTO. This scholarship is made annually thanks to an endowment by former WRRC Director L. Stephen Lau and his wife Virginia.

WRRIP 104B Grants

The TTO reviewed and selected funding proposals made under the WRRIP 104B program.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	9	0	0	0	9
Masters	4	0	0	0	4
Ph.D.	5	0	0	0	5
Post-Doc.	2	0	0	1	3
Total	20	0	0	1	21

Notable Awards and Achievements

Initial funding and findings on project 2016AS457B led to principle investigator securing an additional $979,927.00 from the USDA to further study the optimization of irrigation scheduling.

PI Tsang received a Faculty Research Travel Award in the amount of $2,000.00 to present work related to this project at the American Geophysical Union meeting, Dec. 12-16, 2016, San Francisco.

Yu-Fen Huang, the student supported by this project, is awarded student travel fund ($500) to participate in the CUAHSI and the National Center for Atmospheric Research (NCAR) 3 day hands on training workshop on the use and applications of the Community WRFHydro Modeling.

Data collected through 2016HI461B were leveraged for a new proposal, “Heeia Mangrove Removal Project” awarded to Co-PI Alegado from the State of Hawaii Department of Health in the amount $31,000.00